AD-A208 906

DTIC ACCESSION NUMBER

PHOTOGRAPH THIS SHEET

DTIC FILE COPY

LEVEL

INVENTORY 1

USAARL Rept # 86-7

DOCUMENT IDENTIFICATION

APR 1986

DISTRIBUTION STATEMENT

ACCESSION FOR	
NTIS	GRA&I ☒
DTIC	TAB ☐
UNANNOUNCED	☐
JUSTIFICATION	
BY	
DISTRIBUTION /	
AVAILABILITY CODES	
DIST	AVAIL AND/OR SPECIAL
A-1	

DISTRIBUTION STAMP

DATE ACCESSIONED

DATE RETURNED

89 1 23 176

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC

DTIC FORM 70A MAR 86

DOCUMENT PROCESSING SHEET

PREVIOUS EDITION MAY BE USED UNTIL STOCK IS EXHAUSTED.

USAARL REPORT NO. 86-7

THE ROLE OF PEAK PRESSURE IN DETERMINING THE AUDITORY HAZARD OF IMPULSE NOISE

By
James H. Patterson, Jr.
Ilia M. Lomba Gautier
Dennis L. Curd
SENSORY RESEARCH DIVISION
and
Roger P. Hamernik
Richard J. Salvi
C.E. Hargett, Jr.
George Turrentine
Callier Center for Communication Disorders
University of Texas at Dallas
1966 Inwood Road
Dallas, Texas 75235

APRIL 1986

USAARL

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

A202 906

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: USAARL Report No. 86-7	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): The Role of Peak Pressure in Determining the Auditory Hazard of Impulse Noise	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): James H. Patterson, Jr., Ilia M. Lomba Gautier, Dennis L. Curd, Roger P. Hamernik, Richard J. Salvi, C.E. Hargett, Jr., and George Turrentine	8. CONTRACT OR GRANT NUMBER(s): DAMD 17-80-C-0109
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Sensory Research Division, US Army Aeromedical Research Laboratory, Fort Rucker, Alabama 36362-5000	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62777A, 3F162777A878 AA,136 3E16773A819 00,041
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Medical Research & Development Command, Fort Detrick, Frederick, Maryland 21701-5012	12. REPORT DATE: April 1986
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Impulse Noise
Hearing
Chinchilla
Audiometry
Histology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ABSTRACT:

Most current Damage Risk Criteria (DRC) for human exposure to impulse noise are written in terms of peak pressure as the primary index of the traumatic potential or hazard associated with exposure to an impulse noise. Since the peak pressure is only one of many parameters of an impulse, there is a question whether or not a DRC based on peak pressure can reflect accurately the hazard to hearing posed by impulse noise. The experiments described in this report were designed to determine whether peak pressure is an adequate quantifier for an impulse noise DRC. The general approach was to construct two types of impulse noise with the same Fourier pressure spectrum, but with different peak pressures. This makes it possible to compare the hearing loss and injury resulting from impulses which have the same total energy distributed the same way across frequency, but with different peak pressures. We also can compare injury from different levels. A total of 36 animals were divided into six groups (six animals/group). Groups 1 and 2 were exposed to impulses having approximately equal energy, but with peak pressures that differed by 8 dB. Similarly, groups 3 and 4 and groups 5 and 6 formed pairs of exposure groups where the energy was equivalent, but the peak pressure differed by 8 dB. Threshold shift was measured for 30 days postexposure and injury to the cochlea was determined by examination of surface preparations of the basilar membrane. The threshold shift measured during the first few hours after exposure showed systematic variation with both peak pressure and energy level. The permanent threshold shift (20 to 30 days postexposure) and the loss of sensory cells showed strong dependence on energy level, with a less pronounced dependence on peak pressure. These results indicate that peak pressure is not a sufficient indicator of auditory hazard; however, energy alone is not a sufficient indicator either.

Notice

Qualified requestors

Qualified requestors may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the US Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Animal use

In conducting the research described in this report, the investigators adhered to the Guide for Laboratory Animal Facilities and Care, as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences-National Research Council.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:

BRUCE C. LEIBRECHT
LTC, MS
Director, Sensory Research Division

Released for publication:

J. D. LaMOTHE, Ph.D.
COL, MS
Chairman, Scientific Review Committee

DUDLEY R. PRICE
Colonel, MC
Commanding

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

FIGURE NO. PAGE NO.

APPENDIXES

APPENDIX PAGE NO.

INTRODUCTION

Most current Damage Risk Criteria (DRC) for human exposure to impulse noise are written in terms of peak pressure as the primary index of the traumatic potential or hazard associated with exposure to an impulse noise. Since the peak pressure is only one of many parameters of an impulse, there is a question whether or not a DRC based on peak pressure can reflect accurately the hazard to hearing posed by impulse noise.

The current US Army recommendation on what constitutes hazardous impulse noise is traceable to the 1968 report from the NAS-NRC Committee on Hearing, Bioacoustics, and Biomechanics (CHABA, 1968). The impulse noise limit stated in the CHABA document was based on the scant data available at the time and was defined in terms of peak pressure, A-duration, and B-duration. The authors of the CHABA document recognized the potential shortcomings and included a series of disclaimers which are typified by the statement: "While these curves do no great violence to the published data on either Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS) from impulse noise ... they admittedly represent only a first attempt at a reasonable DRC for exposures to impulse noise. Parameters that are ignored in the present criterion may eventually be shown to be important." This was an open invitation for further refinement of this DRC through additional research.

This research has by-and-large not materialized. This DRC has, however, formed the basis for the current versions of the two Army documents which restrict noise exposure. The first document, TB-MED-501 (DA 1972) "simplified" the original criterion by ignoring durations and setting a conservative limit of 140 dB on the peak sound pressure level. Consequently, whenever impulse noise exceeds 140 dB peak SPL, TB-MED-501 dictates that hearing conservation measures must be taken. The second US Army document based on the CHABA criterion is MIL-STD-1474B(MI) (DoD 1975). This standard specifies noise limits for Army material. Different limits apply depending on what hearing protection can be used with the equipment. These limits are simply the CHABA limits adjusted for an arbitrary amount of protection (29 dB or 35.5 dB) afforded by hearing protective devices. Since these two Army documents are traceable to the original CHABA criterion, their validity rests in part on the validity of this criterion. Unfortunately, the necessary research to establish the technological data base required for determining the validity of this standard has not been forthcoming.

The United Kingdom (Forrest, 1984) has adopted a noise limit standard very similar to that of the US Army. The basic

parameters used to assess hazard are identical; only the limiting level is different due to a difference in percentage of protection. The Netherlands and West Germany employ standards (Smoorenburg, 1982; Pfander, 1975; Pfander et al., 1980) which use a peak pressure criterion as in the US documents except that the impulse duration is defined differently. Only the French (Dancer, 1984) recently have adopted a standard which is not based on peak pressure. They use the A-weighted energy of an impulse in their noise limits.

One of the primary shortcomings of the earlier research was that it focused primarily on peak pressure as a quantifier of impulse noise exposures. There has been an almost complete lack of attention to the distribution of acoustic energy across frequencies. In most cases, it is now impossible to reconstruct the energy density spectra of the impulses used in many of the early studies because the peak measures reported do not contain sufficient information to permit this calculation. The general lack of research in this area has left most of the questions posed by the authors of the original CHABA DRC still unanswered.

The experiments described in this report were designed to determine whether or not peak pressure is an adequate quantifier for an impulse noise DRC. The general approach was to construct two types of impulse noise waveform with the same Fourier pressure spectrum, but with different peak pressures (i.e., with a different phase spectrum). This makes it possible to compare the hearing loss and injury resulting from impulses which have the same total energy distributed the same way across frequency, but with different peak pressures. Also, we can compare injury from impulses having the same peak pressure and different energy levels. For the limited range of exposure parameters used in these experiments, this approach provides a test of the sufficiency of using peak pressure as a predictor of auditory hazard.

METHODS AND PROCEDURES

The experiments that are described here follow a relatively straightforward paradigm: Preexposure measures of hearing are obtained on each animal; the animal is exposed to the impulse noise; following exposure, the animal's hearing thresholds are remeasured at various postexposure times; then following a fixed period of recovery, the sensory structures of the cochlea are prepared for histological examination. Such a paradigm allows for comparisons to be made among variables, such as (1) the physical exposure conditions, (2) temporary changes in hearing, (3) permanent changes in hearing, and (4) the extent and nature of the cochlear damage.

Subjects: The subjects were monaural chinchillas aged from not less than 12 to approximately 49 months at the start of the study. Each animal was made monaural by surgically destroying the left cochlea, thus deafening each animal in the left ear. The surgery was performed with the animal anesthetized to surgical depth using halothane gas. An incision was made in the skin over the ventral surface of the auditory bulla and a small hole was made in the bone of the bulla to provide access to the cochlea. Then, the cochlea was destroyed using a small metal pick to break the bone away from each turn of the cochlea (Miller, 1970). The animals were allowed at least 1 week postoperative recovery time before proceeding with the audiometric training and testing.

Audiometric Apparatus: The audiometric instrumentation has been previously described in detail by Burdick et al., 1978. The chinchillas were tested in a double-grilled cage within a 1200 Series Industrial Acoustics Company (IAC)* sound room. Mounted on the cage was a row of photocells to detect the animal's location and an electronic buzzer which was used as a secondary reinforcer. A synthesized signal generator (Fluke Model 6010A*), an attenuator, and an amplifier were used to generate and adjust the signal level. The pure tone signals were delivered through an Altec coaxial loudspeaker.* The control, duration, and sequencing of events, as well as recording, were accomplished using a microprocessor. The behavior of the animals was monitored on a closed circuit television.

Training and Threshold Testing Procedures: The procedures for training and testing the animals were similar to those described previously (Burdick, et al., 1978). The animals were conditioned to avoid an AC electric shock (1.4 mA nominal level) by crossing from one compartment to the other of the double-grilled cage during a 3.84-s trial interval during which a pulsed, pure-tone signal was presented. Each trial interval consisted of three tone pulses with 720ms on-times separated by 560ms off-times. The tone pulse had an exponential rise and decay function with a first time constant of 14 ms. When the avoidance response was made, the signal was terminated immediately. If the subject failed to cross from one compartment to the other during the trial interval, a shock and buzzer were presented simultaneously until the crossing response was made. This resulted in the termination of the shock, buzzer, and signal.

Each group of subjects received training sessions until all subjects scored 95 percent correct for three successive sessions. During the training sessions, the animals were given one trial at

*See Appendix F

each of the following nine frequencies: 0.125, 0.25, 0.5, 1.0, 1.4, 2.0, 4.0, 5.7, and 8.0 kHz. Later in the experiments, 2.8 kHz was added to the test frequencies. The intensities of the tones varied over a 15 dB range (50-65 dB SPL re: 20 uPa) during all the training sessions. During the first training sessions, trials were presented with an average intertrial interval of 60 s. Then trials were presented for one or more sessions using intertrial intervals of 45, 30, and finally 20 s. Once this was accomplished, all subsequent training and testing was performed using a 20 s intertrial interval. Once the training criterion was obtained, threshold determinations were begun.

A modified method of limits (Burdick, et al., 1978; Miller, 1970) was used to estimate thresholds. On the first trial of a threshold measurement, the signal level was set to 40 dB below the full output (dB) calibration level for the particular test frequency. An additional randomly set attenuation of up to 10 dB was added to the initial 40 dB for each frequency. The initial signals could range from 40-65 dB SPL. A correct response at this first presentation level resulted in a further 20 dB reduction in level for the next trial and so on, until the animal failed to respond.

On the trial following a miss, the level of the signal was increased 10 dB and the threshold was taken as the level half way between the lowest level that was responded to correctly and the highest level missed. After threshold values began to stabilize, which required from 8-10 complete audiograms, a threshold value was discarded if it differed by 15 dB from the values in Table 1 and a second threshold measurement was taken. The threshold obtained on the second determination always was accepted. A sham trial always followed the last trial of each threshold determination. This was done to obtain an estimate of the rate of spontaneous responding. These trials were identical to the regular trials except that the synthesizer was set to "zero" frequency and the shock and buzzer were turned off. There was no consequence to the animal for spontaneous responses. Shock was turned off and only the buzzer was used as a secondary reinforcer when the signal level was within 10 dB of the values in Table 1.

Audiograms were taken until the average threshold was within plus or minus 5 dB of the average of the values in Table 1 on the five consecutive sessions. Then audiograms were continued until the day of exposure. The last five audiograms before exposure were averaged across sessions to produce the baseline audiogram for the particular animal. The baseline audiogram for each animal was used as a reference for computing the postexposure threshold shifts. A complete listing of individual animal preexposure thresholds, group average audiograms, and the total averaged preexposure audiograms for all 36 animals is presented in Appendix A.

Exposure Stimuli: Two types of impulses were synthesized for use as exposure stimuli. One of these, called the high peak stimulus, is the result of applying a 200-microsecond rectangular pulse to the exposure circuit described here. The second type of impulse, the low peak stimulus, was computed using a procedure described by Patterson and Green (1970). Briefly, a digital impulse was passed through a bank of digital all-pass filters: This produced a signal whose amplitude spectrum is the same as the original impulse, but with an altered phase spectrum and, consequently, an altered time history. To produce the low-peak impulses 25 elemental all-pass filters were selected from a set of 50 possible elemental filters. The selection was made by generating several hundred of the combinations of 50 filters chosen 25 at a time and picking the signal with the lowest peak.

TABLE 1

REFERENCE NORMAL AUDIOGRAM FOR THE CHINCHILLA BASED UPON THE DATA OF MILLER, 1970 AND BURDICK ET AL., 1978

	Frequency kHz									
	0.125	0.250	0.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0	Mean
Reference Level dB (SPL)	25	10	0	0	0	0	0	0	0	5	4

The exposure stimuli were synthesized on a PDP 11/34 minicomputer* or an SEL Systems 85* and converted to electrical pulses by a 16 bit digital-to-analogue (D-A) converter. The output of the D-A converter was low pass filtered at 5.0 kHz by a Rockland System 886*, 8 pole Bessel filter. Then this signal was amplified through an Altec amplifier* and converted to acoustic impulses by an Altec 290D driver.* A 10 cm extension throat with 4.8 cm diameter opening was bolted to the driver. Figures 1 and 2 show the time history and spectrum of the high peak and the low peak impulse, respectively. These spectra are essentially the amplitude response of the Altec 290D driver. When these two impulses are equated for total energy (and energy spectrum), there is an 8 dB difference in the peak pressures as well as a difference in when the peak of the impulse occurs.

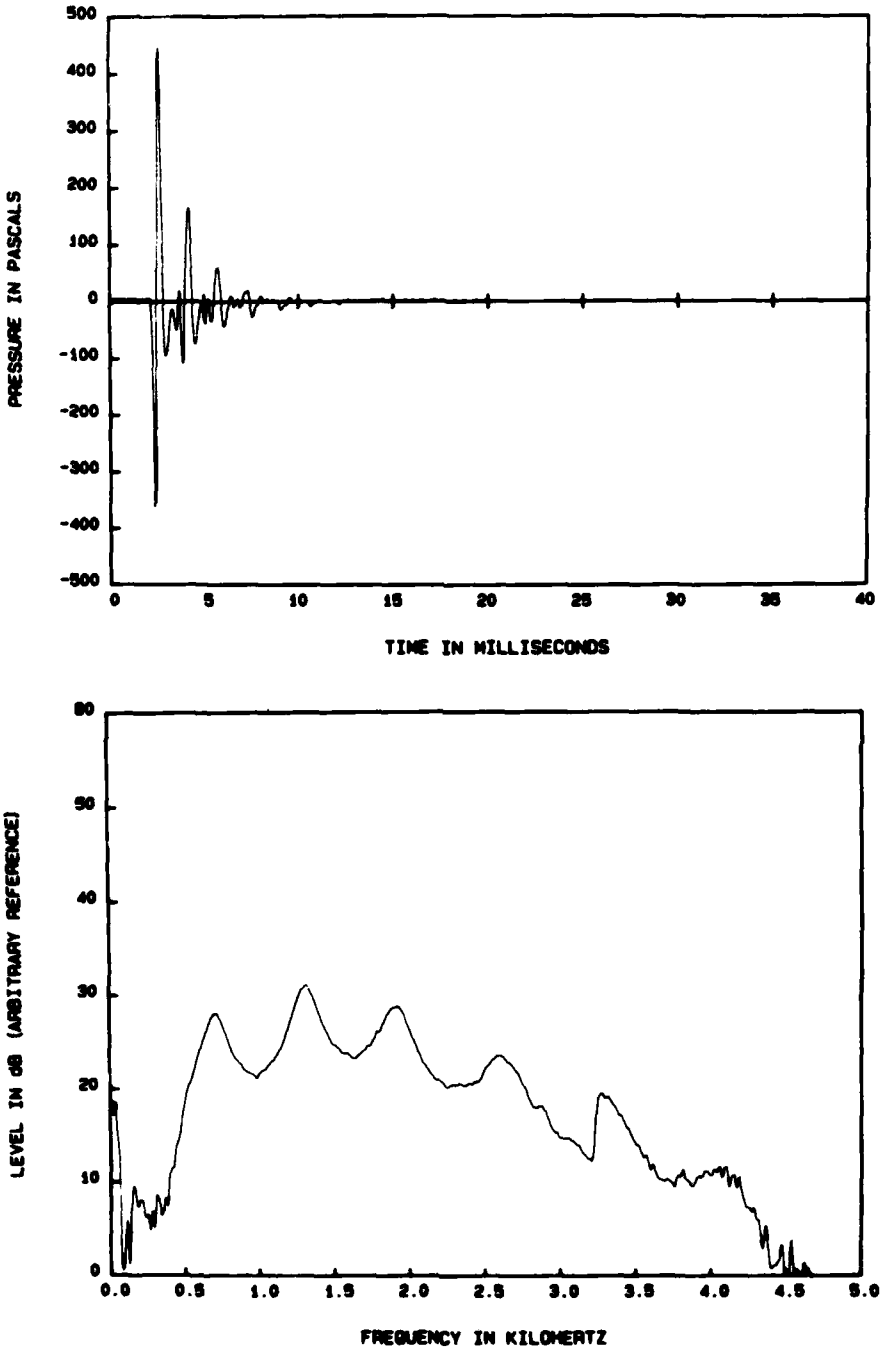


FIGURE 1. The high-peak impulse pressure-time waveform (upper) and the frequency spectrum of the impulse (lower).

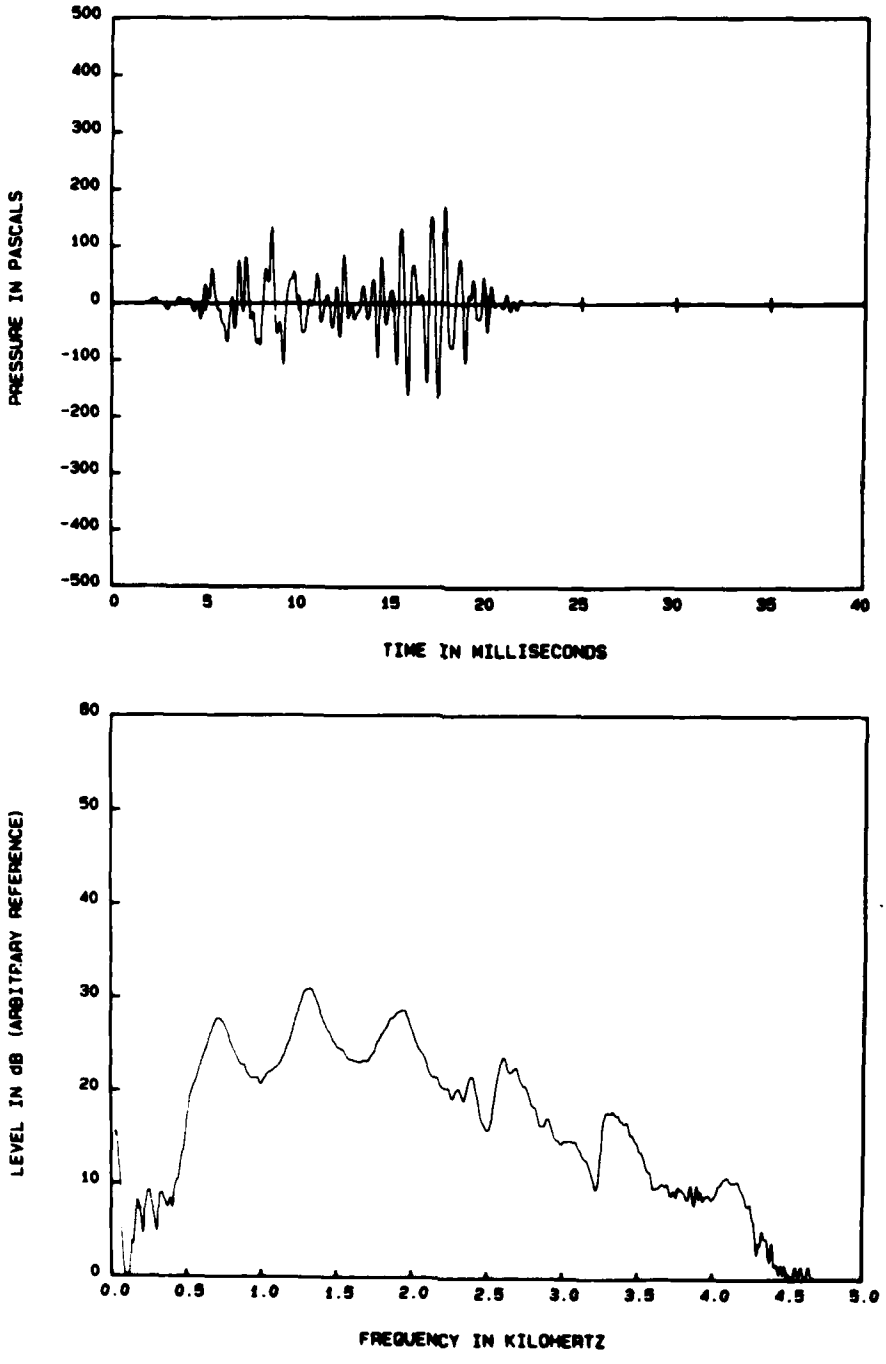


FIGURE 2. The low-peak impulse pressure-time waveform (upper) and the frequency spectrum of the impulse (lower).

Before each exposure, the impulses emitted by the high intensity driver were calibrated. A 1/4-inch condenser microphone (B&K type 4135*) was positioned with the diaphragm at grazing incidence in the center of the opening of the extension throat and 1 mm outside the throat. All levels and spectra were measured with this setup, but with no animal present. The microphone remained in place to record the exposure impulses.

The animal was positioned with the entrance of the ear canal at the center of the driver extension throat. The animal's pinna was taped to a flange on the throat which served to stabilize the positioning of both the ear canal and the pinna. Casual observation indicated stabilizing the pinna was necessary since animals would fold the pinna back along the head and possibly close the ear canal. Figure 3 shows the exposure setup with the animal in place.

Each exposure consisted of 100 impulses of the same wave shape (high or low peak) presented at constant intensity throughout. The impulses were delivered at a rate of one every 3 seconds with timing controlled by the computer. The entire sequence of impulses was recorded on a Nagra IV-S recorder.*

Experimental Design. A total of 36 animals were used in these experiments. They were divided into six groups (six animals per group) and exposed to the impulse conditions presented in Table 2. Groups 1 and 2 were exposed to impulses having approximately equal energy, but with peak pressures that differed by 8 dB (See Appendix E for an outline of the energy calculation procedure). Similarly, groups 3 and 4 and groups 5 and 6 formed pairs of exposure groups where the energy was equivalent, but the peak pressures differed by 8 dB. On the other hand, groups 2 and 3 received exposures where the peak pressures were equal, but the energy differed by 8 dB. An attempt was made to match groups 4 and 5 with respect to peak pressure; however, after gathering preliminary data, it was apparent that the high peak stimulus produced virtually no effect at a peak of 131 dB. Therefore, the peak level for group 5 was set at 135 dB and group 6 at an equivalent energy level. This arrangement of two wave types crossed with three energy levels fits the analysis of variance model for a two-factor independent group experiment. In order to analyze all frequencies simultaneously, audiometric test frequency was added as a third factor with repeated measures (Winer, 1971).

Recovery Conditions: Complete audiograms were obtained starting 2 minutes after an exposure (referred to as time t=0) and at postexposure times of 32, 62, 92, 182 and 362 minutes, 24 and 48 hours, 6, 9, 13, 16, 20, 23, 27, and 30 days after exposure. Temporary Threshold Shifts (TTS) for each animal were calculated from each postexposure audiogram by subtracting the

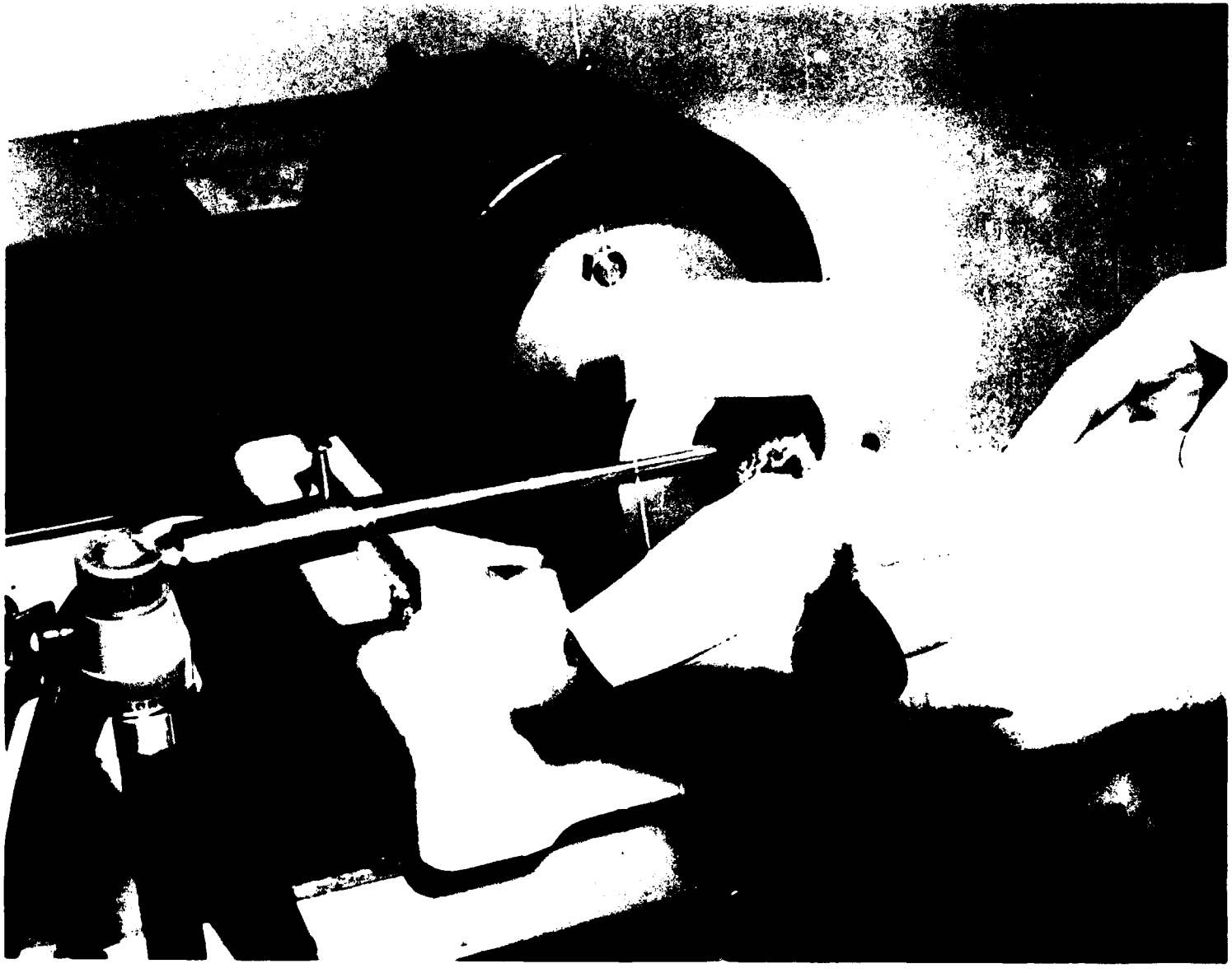


FIGURE 3. An overview of the exposure setup with the chinchilla in place.

animal's baseline audiogram. The threshold shifts for each animal obtained at 20, 23, 27, and 30 days postexposure were averaged to produce an estimate of the animal's Permanent Threshold Shift (PTS). The individual animal's TTS or PTS data were averaged across all animals constituting a particular group to obtain the group average TTS or PTS. A complete tabulation of individual animal threshold shift data and averaged group data is presented in Appendix B.

TABLE 2

IDENTIFICATION OF THE EXPOSURE CONDITIONS FOR THE SIX EXPERIMENTAL GROUPS

Subject Group	Stimulus Type	Peak Pressure (dB SPL)	Energy per Unit Area Per Impulse (J/M^2)	Total Energy Level of the Exposure (dB re: $1 J/M^2$)
1	High Peak	147	.095	9.78
2	Low Peak	139	.097	9.87
3	High Peak	139	.015	1.76
4	Low Peak	131	.015	1.76
5	High Peak	135	.006	-2.22
6	Low Peak	127	.006	-2.22

Histology: At 88 to 90 days postexposure, the animals were anesthetized with halothane and then decapitated. Following decapitation, the two auditory bullae were removed and opened widely. The right stapes was removed and the round window membrane was slit. A fixation solution consisting of 2.5 percent glutaraldehyde in 0.1 M PO_4 buffer was perfused through the right cochlea. Typically, the left cochlea was not perfused except for immersion in fixative since the monauralization procedure resulted in virtually a complete destruction of the cochlea. After a variable period of glutaraldehyde fixation the right cochlea was postfixed in 1 percent osmium tetroxide in 0.1 M PO_4

buffer, washed in buffer, and then dehydrated to 70 percent ETOH. The entire basilar membrane and stria vascularis were piecewise dissected free from their bony attachments and mounted in glycerin on glass slides for a surface preparation, light microscopic analysis (Engstrom, Ades, and Anderson, 1966).

Inner and outer hair cell populations were determined on a percentage basis as a function of distance along the cochlear duct. Baseline normal sensory cell populations were established at octave lengths along the cochlea using a large population (N=30) of normal chinchillas (Appendix D). Sensory cell counts which eventually yielded cochleograms were performed at a magnification of 500X using a Zeiss-Nomarski light microscope.* A cell was counted as missing when the cell body was not present. Alternatively, in animals that have survived more than 30 days after trauma, the location of missing cells is usually well marked by a characteristic phalangeal scar at the level of the reticular lamina. Cell counts were averaged over 0.24 mm lengths of the organ of Corti as measured along a reference line established by the junction of the inner and outer pillar cells at the highest level of the reticular lamina. A frequency-place map established by Eldridge et al., (1977) was used to superimpose frequency coordinates on the length coordinate of the cochleogram so that audiometric data could be related directly to the sensory cell populations along the length of the cochlea. All the light microscopic analyses and graphics were accomplished directly using an LSI 11/23 microcomputer system* with the appropriate morphometric software developed in the histology laboratory. A complete presentation, by experimental group, of all individual cochleograms and superimposed PTS audiograms is presented in Appendix C. Octave band length, percent sensory cell losses, average percent losses across groups, and total sensory cell losses for individual animals are presented in Appendix D.

RESULTS AND DISCUSSION

Preexposure Thresholds: A summary of all preexposure thresholds (dB SPL) for each animal in this study, as well as mean thresholds arranged by exposure groups (1 through 6), and mean thresholds for the entire group of 36 animals are listed in Appendix A. Figure 4 illustrates in graphical form the tabulated thresholds (audiograms) taken from Appendix A. The upper curve represents the audiogram averaged across six animals used in this study, while the lower set of curves shows the mean audiograms for each of the six exposure groups. The group average audiograms are presented in order to illustrate the small amount of variability across the six experimental groups, as well as the close agreement with the normative data of Miller, 1970. Standard deviations for all the preexposure thresholds are presented in Appendix A.

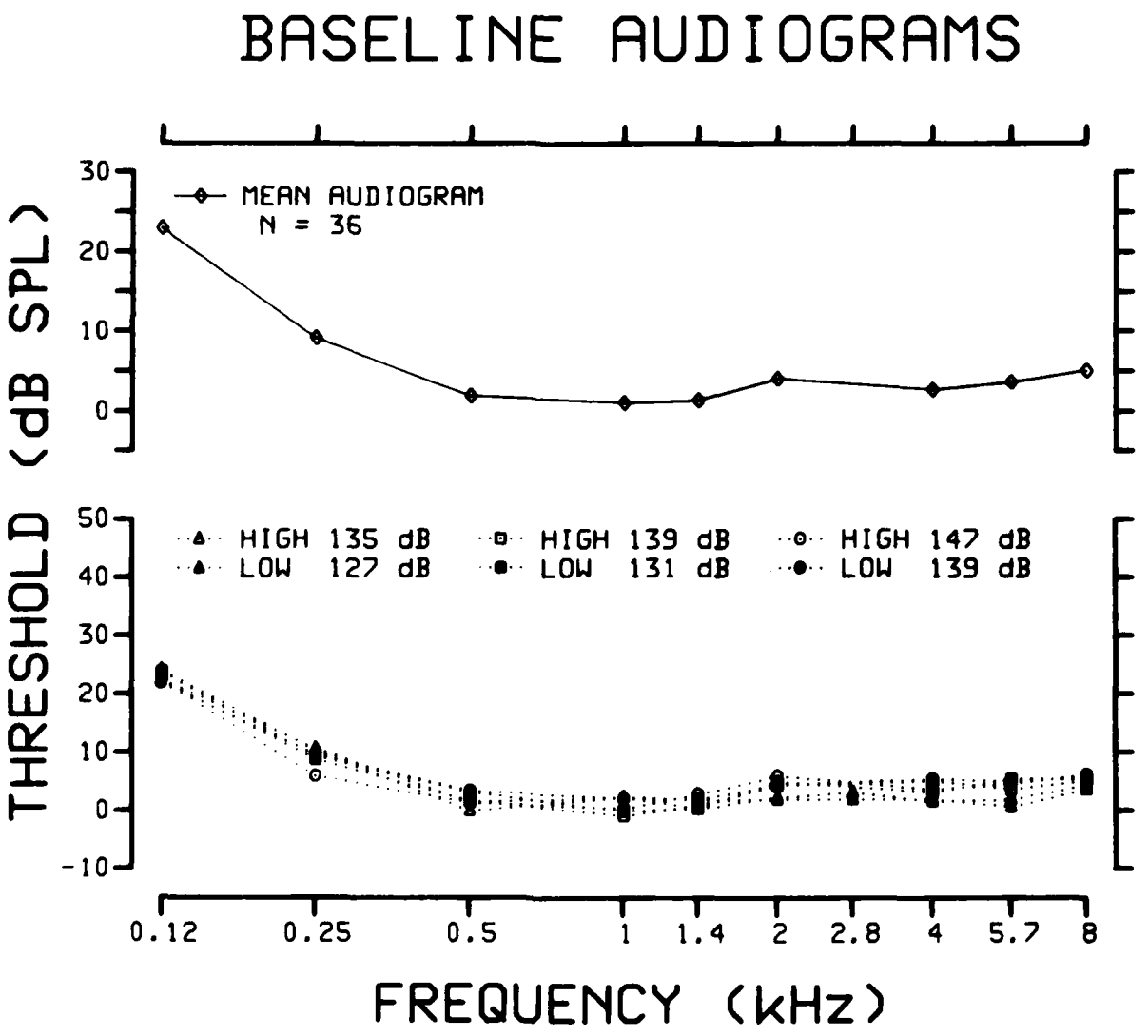


FIGURE 4. Mean preexposure audiograms for all 36 chinchillas (upper) and for the six individual groups identified by exposure conditions (lower).

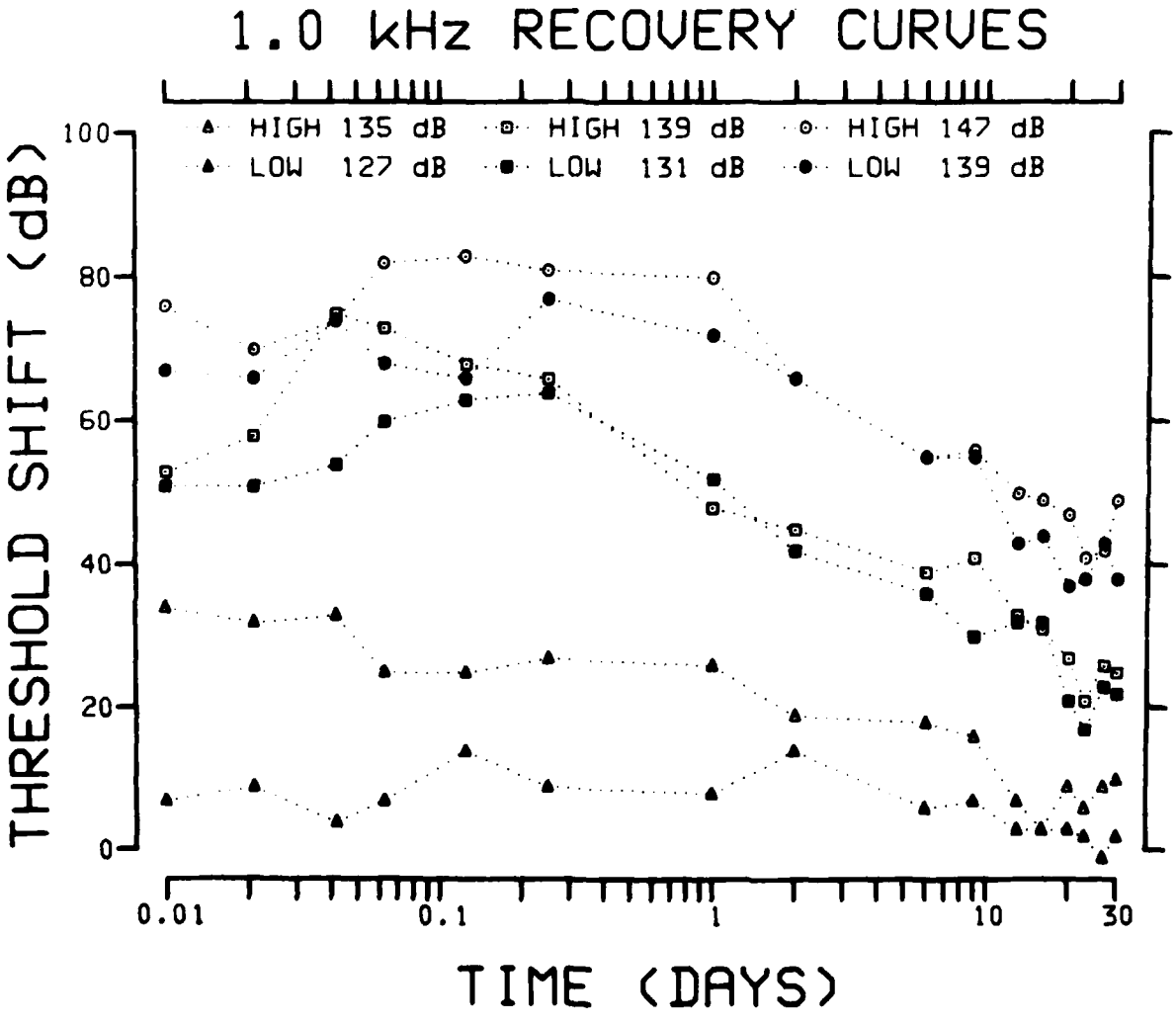


FIGURE 5. The group mean threshold recovery curve for each exposure condition at the 1.0 kHz test frequency.

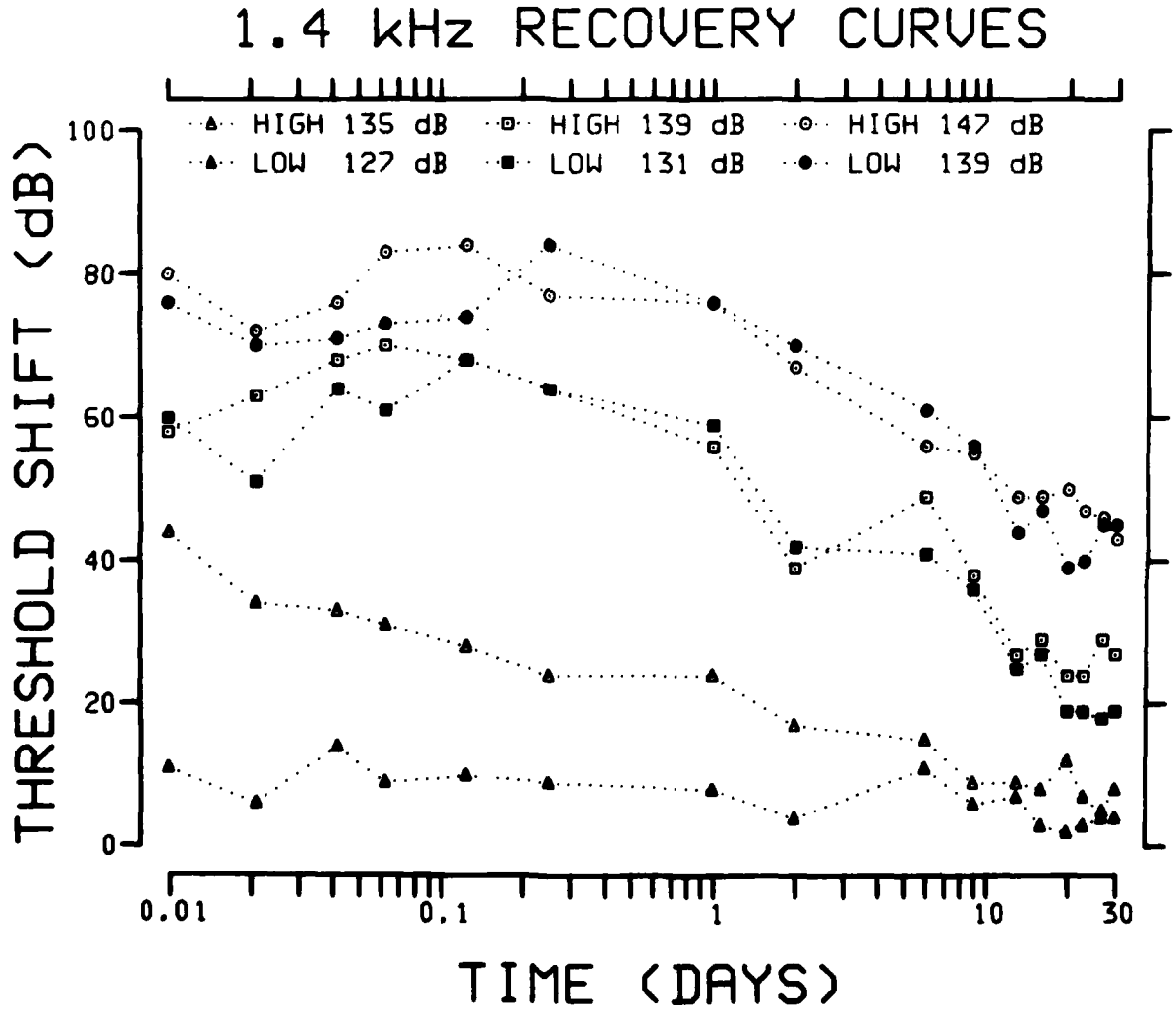


FIGURE 6. The group mean threshold recovery curves for each exposure condition at the 1.4 kHz test frequency.

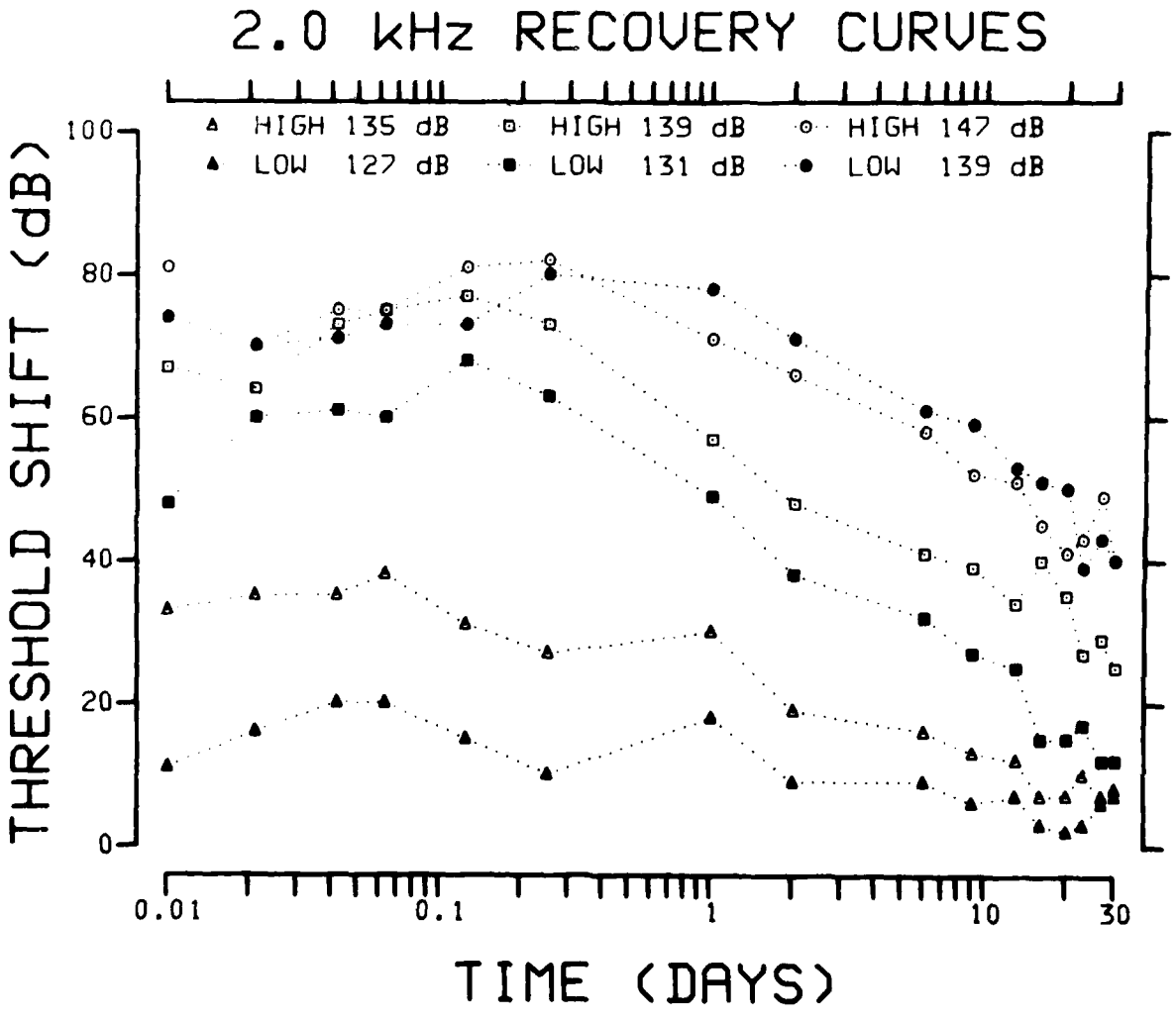


FIGURE 7. The group mean threshold recovery curves for each exposure condition at the 2.0 kHz test frequency.

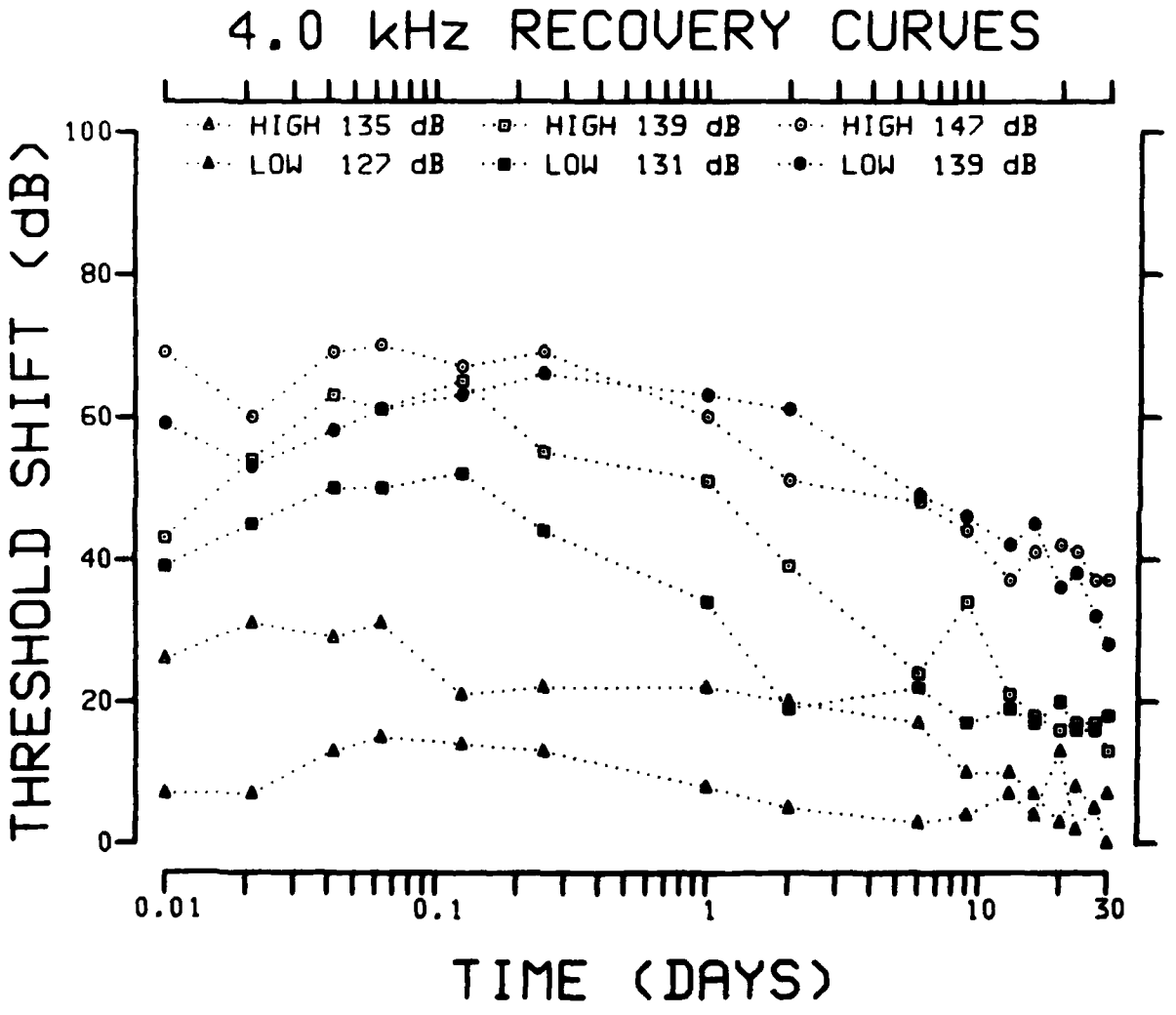


FIGURE 8. The group mean threshold recovery curves for each exposure condition at the 4.0 kHz test frequency.

Postexposure Threshold Shift: The group average threshold recovery curves at 1.0, 1.4, 2.0, and 4.0 kHz for all six experimental groups over a period of 30 days are shown in Figures 5 through 8. The following observations can be made from the data presented in these four figures: The overall temporal configuration of the recovery curves is similar. In general, each of the recovery curves can be broken into two parts; the early phase $0<t<24$ hours (t = postexposure time) and a later phase $1<t<30$ days. During the early phase, there is not a consistent pattern to the recovery function, i.e., threshold shifts in general, either do not recover or continue to get worse before an orderly recovery period begins. This phenomena has been described previously (Luz and Hodge, 1971; Henderson and Hamernik, 1982) where it has been referred to as a postexposure growth of TTS. During the later phase there is an orderly recovery of threshold which follows a time course which is approximately linear in log-time, until a relatively stable plateau is reached at around 25-30 days after exposure. The mean threshold shift at this plateau is defined as PTS. In general, there is an orderly increase in the amount of TTS across groups of animals as the energy of the exposure increases.

Traditionally, threshold shift at t=0 has been used as an index of the severity of a noise exposure since for moderate exposures TTSo is usually the maximum shift observed. However, in situations where the recovery function follows a complex biphasic recovery pattern, a more appropriate measure may be the maximum threshold shift (TTSmax) recorded, regardless of when it occurs following an exposure. In Figures 9 and 10, the group mean TTSo and TTSmax audiograms are plotted for each experimental group. In both figures, we get an appreciation for the orderly increase in threshold shift across test frequencies for each group as the energy of the exposure increases. The shift across frequency for each group is relatively flat, and increases from approximately 20-30 dB at the lowest level exposure to 80-90 dB at the highest level exposure. The TTSmax data show a strong compressive or asymptotic effect once threshold shifts exceed approximately 70 dB. At these large threshold shifts, the ability to distinguish between groups on the basis of TTS becomes more difficult.

The relation between impulse intensity (peak pressure) and threshold shift (both TTSo and TTSmax) is interesting. Within groups having approximtely equal energy exposures, there is the tendency in the mean data for the exposures with higher peak pressures to produce greater TTSo and TTSmax. However, in comparing groups with unequal energies, i.e., Group 4, 131 dB low peak exposure with Group 5, 135 dB high peak exposure, the 131 dB exposure consistently produces greater mean TTSo and TTXmax. Such relations between pressure and energy variables hold at the

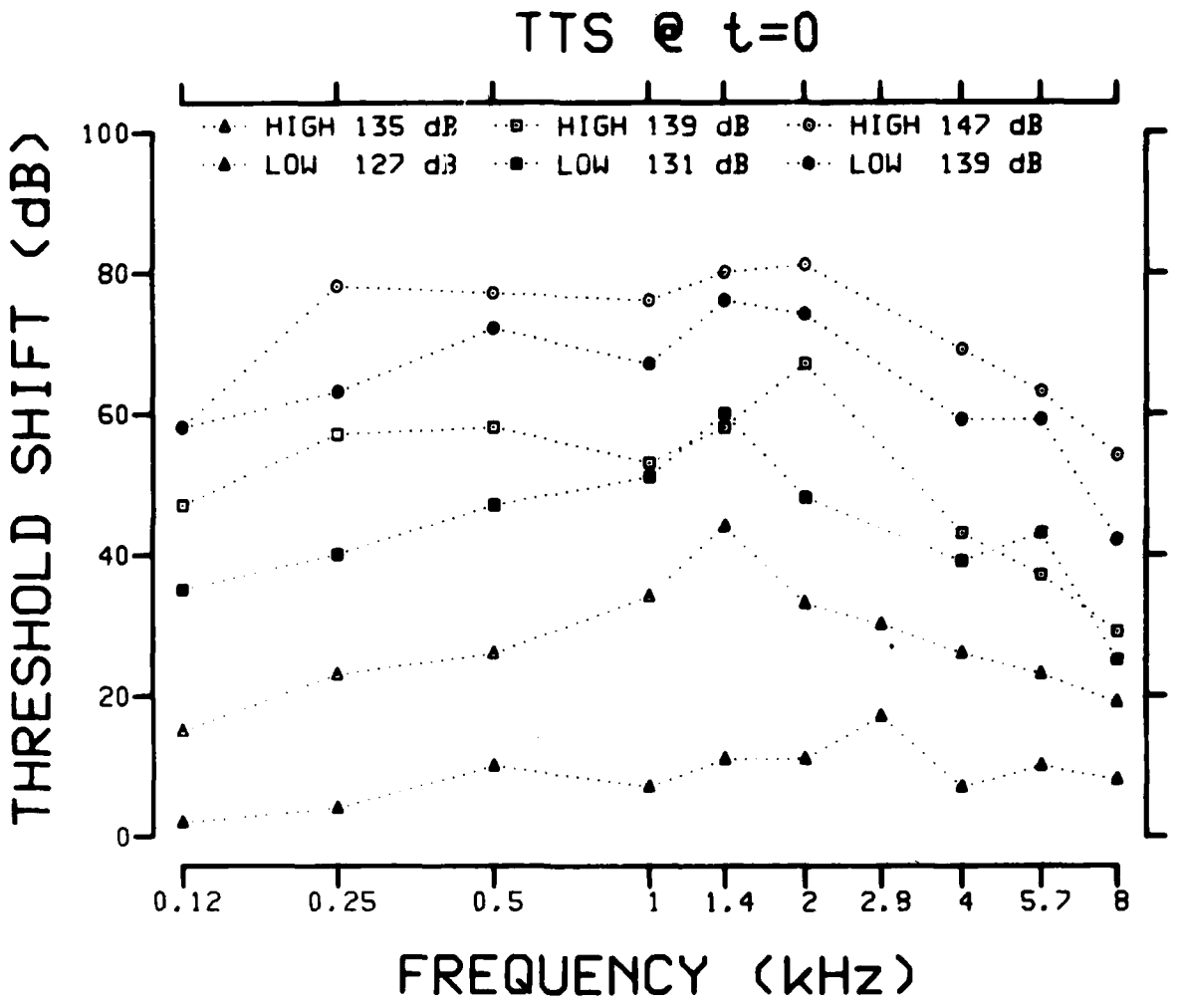


FIGURE 9. The group mean temporary threshold shift immediately following the impulse noise exposure (TTSo) for each of the experimental groups at each test frequency.

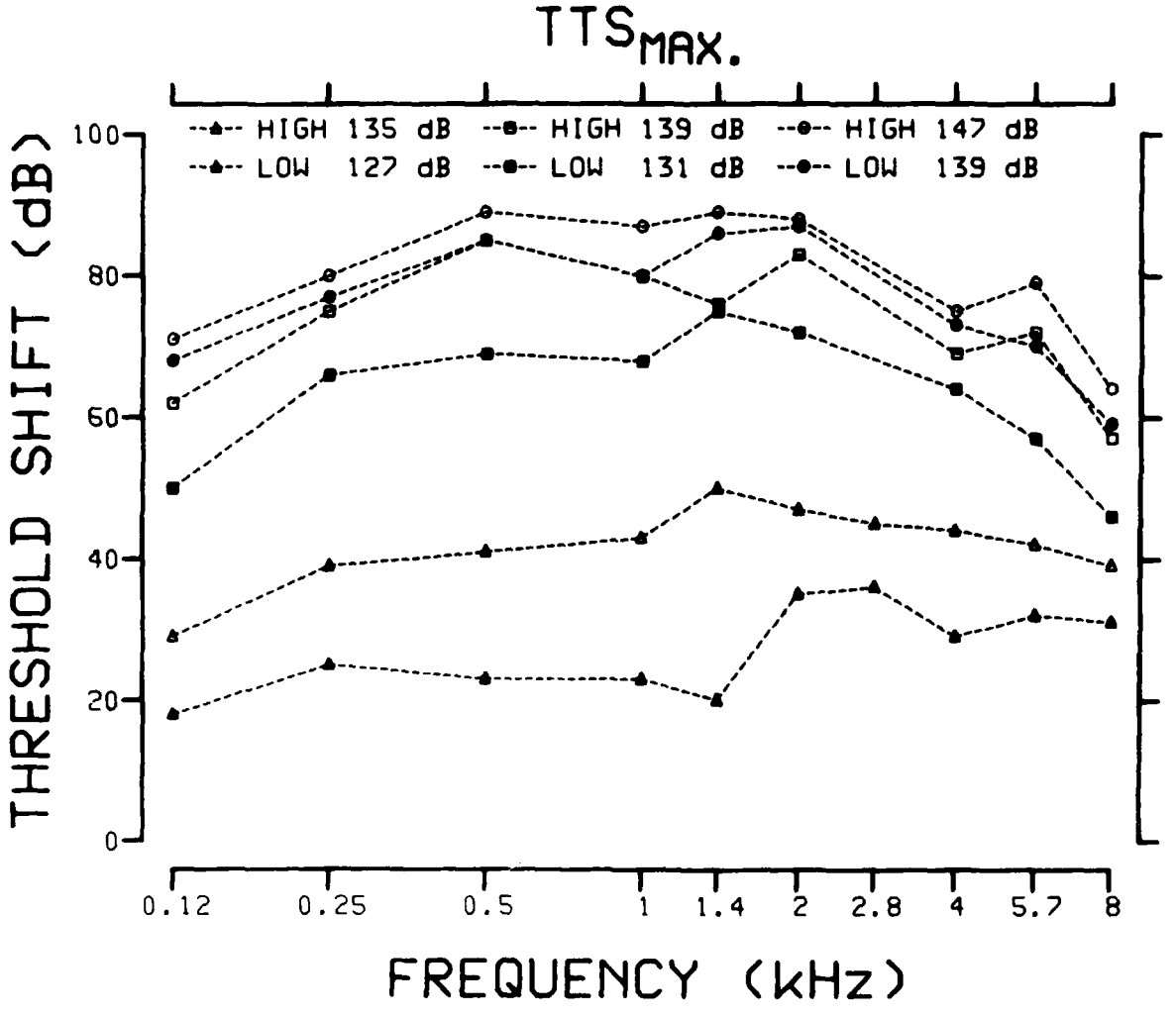


FIGURE 10. The postexposure group mean maximum temporary threshold shift (TTSmax) for each of the experimental groups at each test frequency.

higher levels, but the effects appear less pronounced due to the compressive effect discussed above.

The differences between pairs of exposure groups having equal energies is less pronounced if one considers the TTS data at times t>24 hours. During this late phase of recovery (Figures 5-8) groups with equal energy exposures have similar TTS.

In Figures 11-13, the threshold shift data have been replotted so that TTSo and TTSmax can be directly and more easily compared between pairs of groups having approximately equal energy exposures. In each case for any selected group TTSmax>TTSo, clearly indicating a growth of TTS at nearly all test frequencies for all exposure conditions.

The threshold shift remaining at 20-30 days postexposure was used as a measure of PTS. The last four data points on the recovery functions were averaged for each test frequency to estimate the PTS for each animal (see Appendix B). Figure 14 illustrates the PTS for each exposure group. Within exposure groups the PTS is relatively uniformly distributed across frequency producing a flat audiometric configuration. The PTS generally is well ordered according to increasing energy of exposure with the lowest energy level producing on the average less than 10 dB PTS; moderate energy levels producing on the order of 20 dB PTS, and the highest energy levels producing around 40 dB PTS. This increase of PTS with energy level of the exposure is presented more clearly in Figure 15 where the average PTS at 1, 2 and 4 kHz ($\overline{PTS}$ 1,2,4) is computed and plotted against energy level of the exposure. In addition to the regular increase of PTS with energy level, we also notice that within exposure groups having equal energy, the high peaked waves produce a greater PTS. To determine if this effect was significant, these data were subjected to an analysis of variance (Winer, 1971) with energy level and wave type as the two primary treatment effects. Test frequency was included as a repeated measure factor. Table 3 contains a summary of the analysis of variance. This analysis indicates that not only are energy, test frequency, and the interaction of these two factors significant, but that wave type is marginally significant in the production of PTS.

Histological Correlation: The behaviourly measured hearing losses reported here are, in general, reflected in the distribution of sensory cell loss in the cochlea. Cochleograms, which reflect the spatial (or frequency) distribution of sensory cell loss, are presented for each animal in Appendix C, along with that animal's PTS audiogram. A summary of the group averaged sensory cell losses is shown plotted in Figures 16-18 for all six experimental groups. Each data point in these figures represents the average number of sensory cells lost in

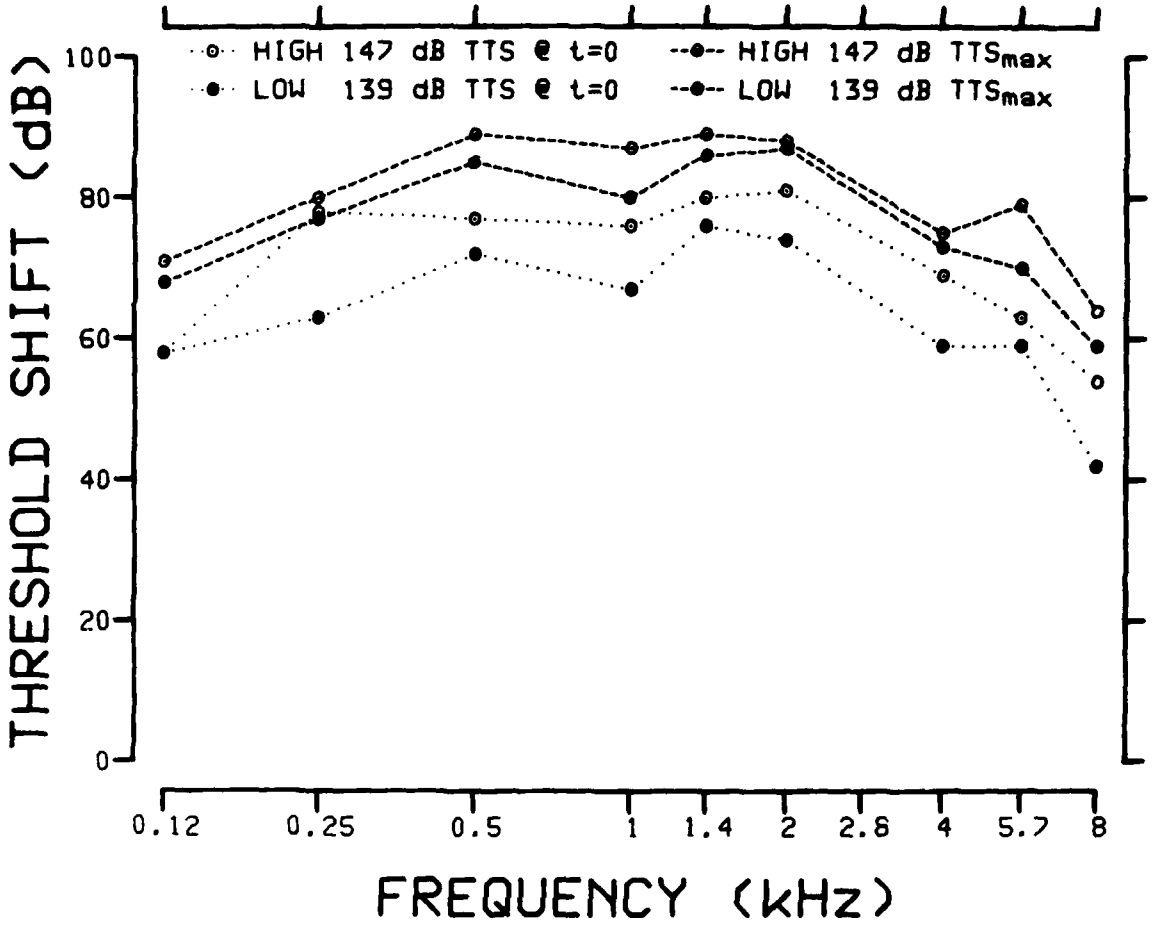


FIGURE 11. The postexposure group mean maximum TTS compared to the TTS measured immediately after exposure for the two groups of animals exposed to the 9.8 dB energy level impulses.

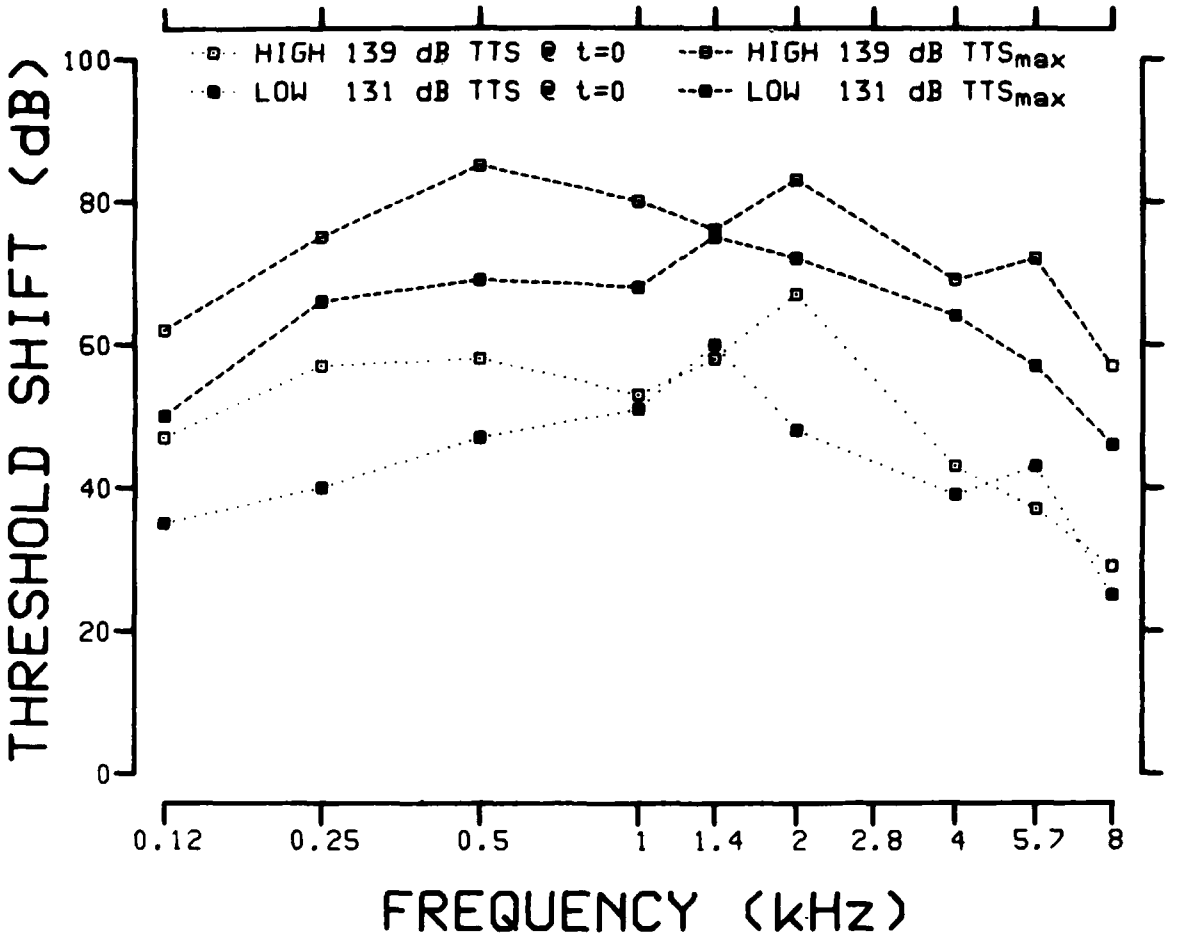


FIGURE 12. The postexposure group mean maximum TTS compared to the TTS measured immediately after exposure for the two groups of animals exposed to the 1.76 dB energy level impulses.

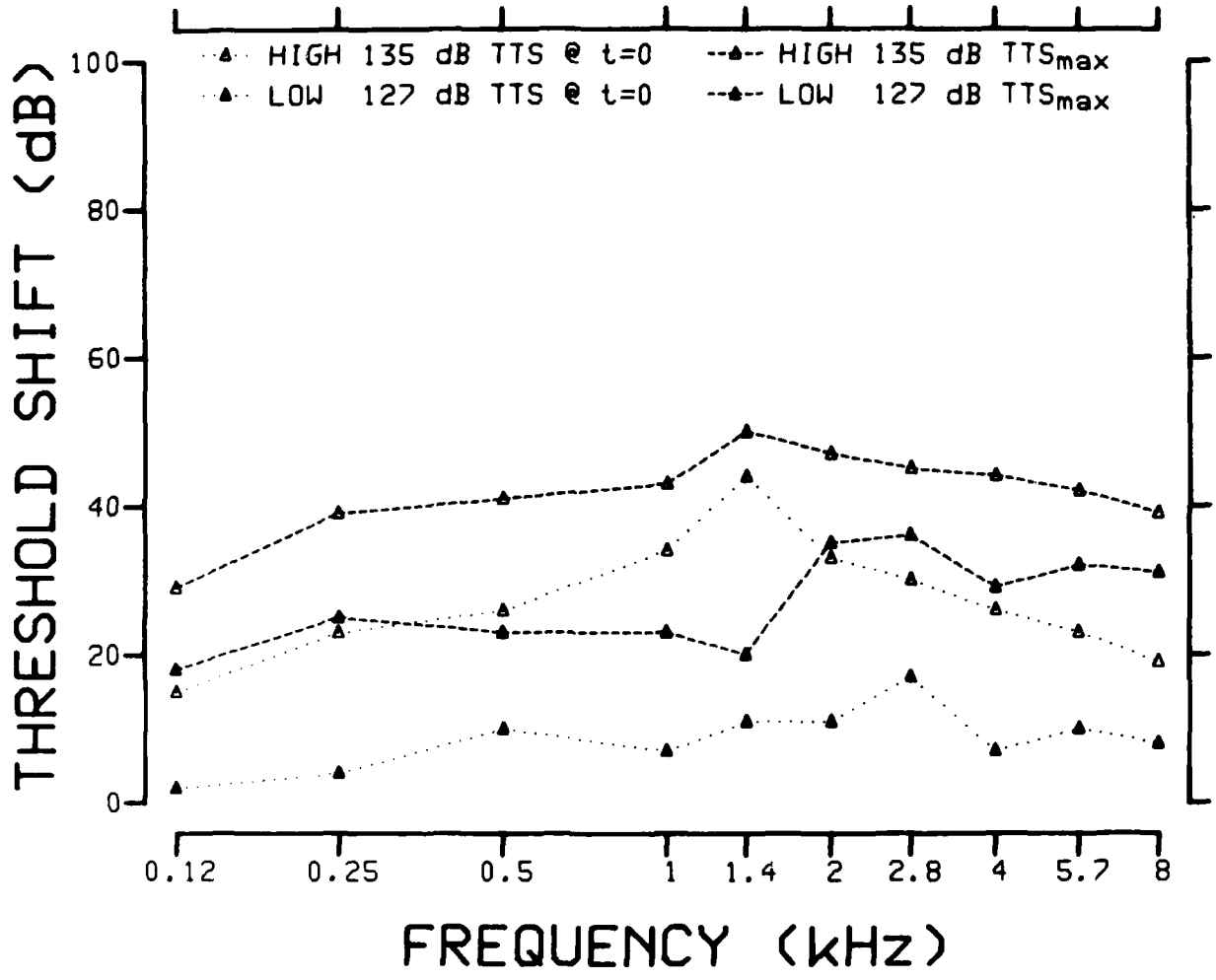


FIGURE 13. The postexposure group mean maximum TTS compared to the TTS measured immediately after exposure for the two groups of animals exposed to the -2.22 dB energy level impulses .

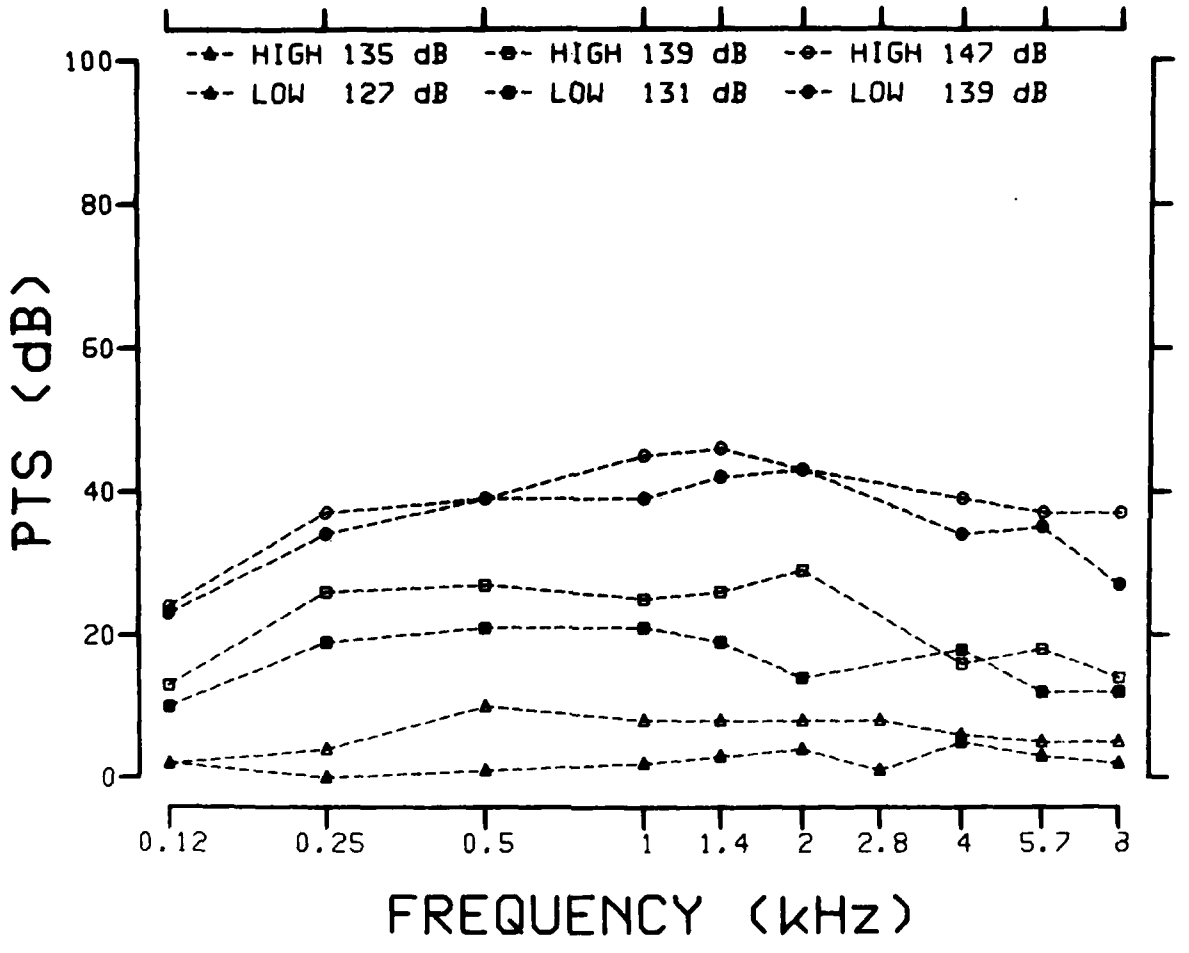


FIGURE 14. The group mean permanent threshold shift at each test frequency for each of the six exposure conditions.

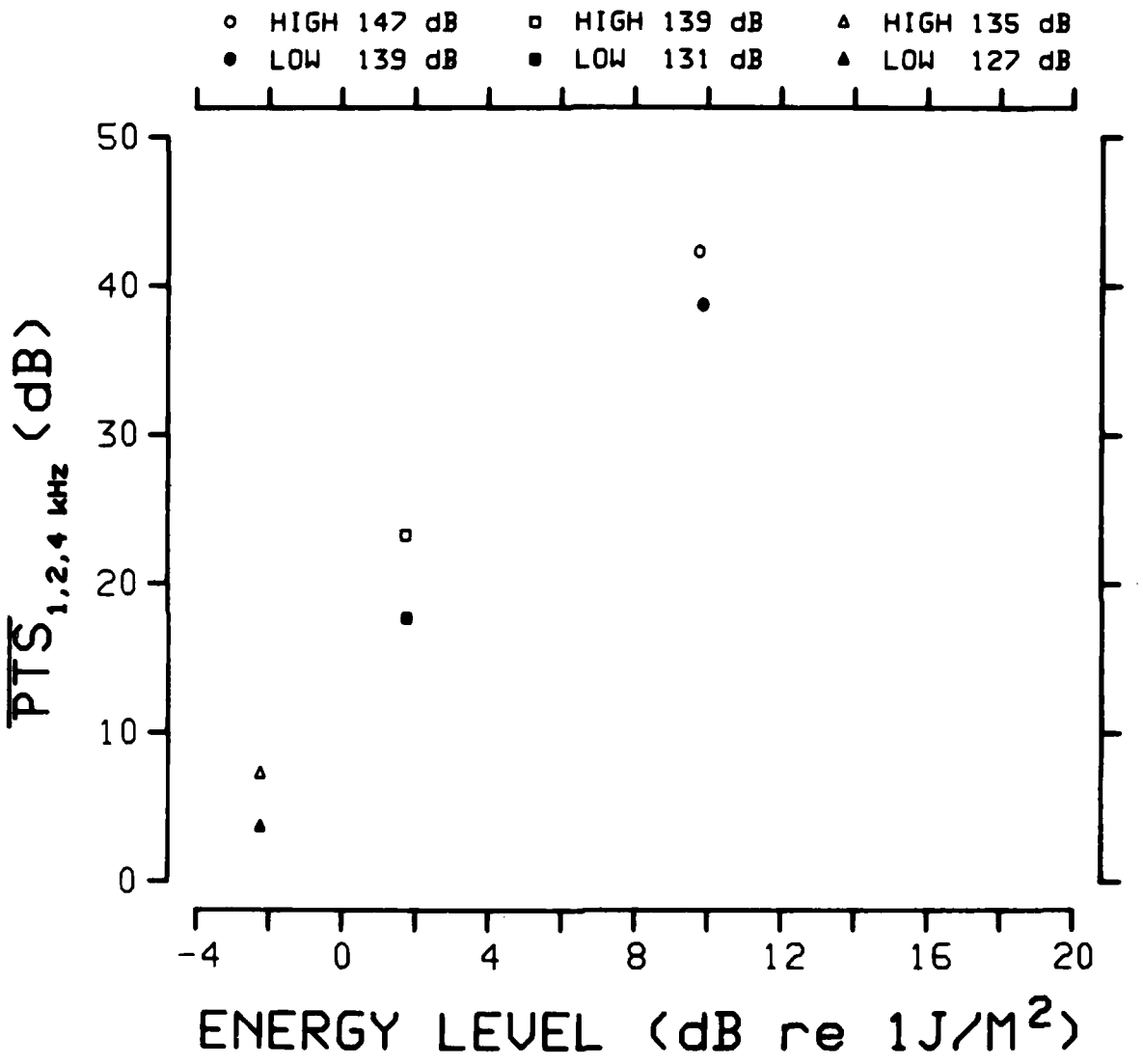


FIGURE 15. The mean PTS computed at 1, 2, and 4 kHz ($\overline{PTS}$ 1,2,4) as a function of the total energy level of the exposure.

the particular experimental group within an octave band length of the cochlea centered at the indicated frequency (i.e., 0.125, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, and 16.0 kHz). The octave band-group average sensory cell loss, in percent, was computed by averaging sensory cell losses within octave band lengths of the cochlea for the individual animals that constituted that particular group, and dividing the loss by the normative sensory cell populations obtained from normal control animals. A complete sensory cell tabulation for individual animals, as well as group means for experimental and control subjects, is presented in Appendix D. Figures 16-18 should be compared to the mean PTS for individual groups plotted in Figure 14. Several generalizations can be made from the group mean cell loss and PTS data.

As in the PTS data, there is an orderly increase in the mean sensory cell loss, both inner hair cells (IHC) and outer hair cells (OHC) as the energy level of the exposure increases.

The sensory cell lesion begins to develop in the 1 kHz region of the cochlea, and with increasing energy levels spreads systematically towards the base of the cochlea. This effect is seen in Figure 19 where all the sensory cell losses from each group are plotted together.

TABLE 3

SUMMARY OF THE ANALYSIS OF VARIANCE ON PERMANENT THRESHOLD SHIFT

TREATMENT	F	DF	P
Wave type	4.26	1/30	<0.05
Energy level	82.87	2/30	<0.001
Wave type by energy	0.08	2/30	>0.1
Test frequency	16.70	8/240	<0.001
Wave type by frequency	0.80	8/240	>0.1
Energy by frequency	3.49	16/240	<0.001
Wave type by energy by frequency	1.36	16/240	>0.1

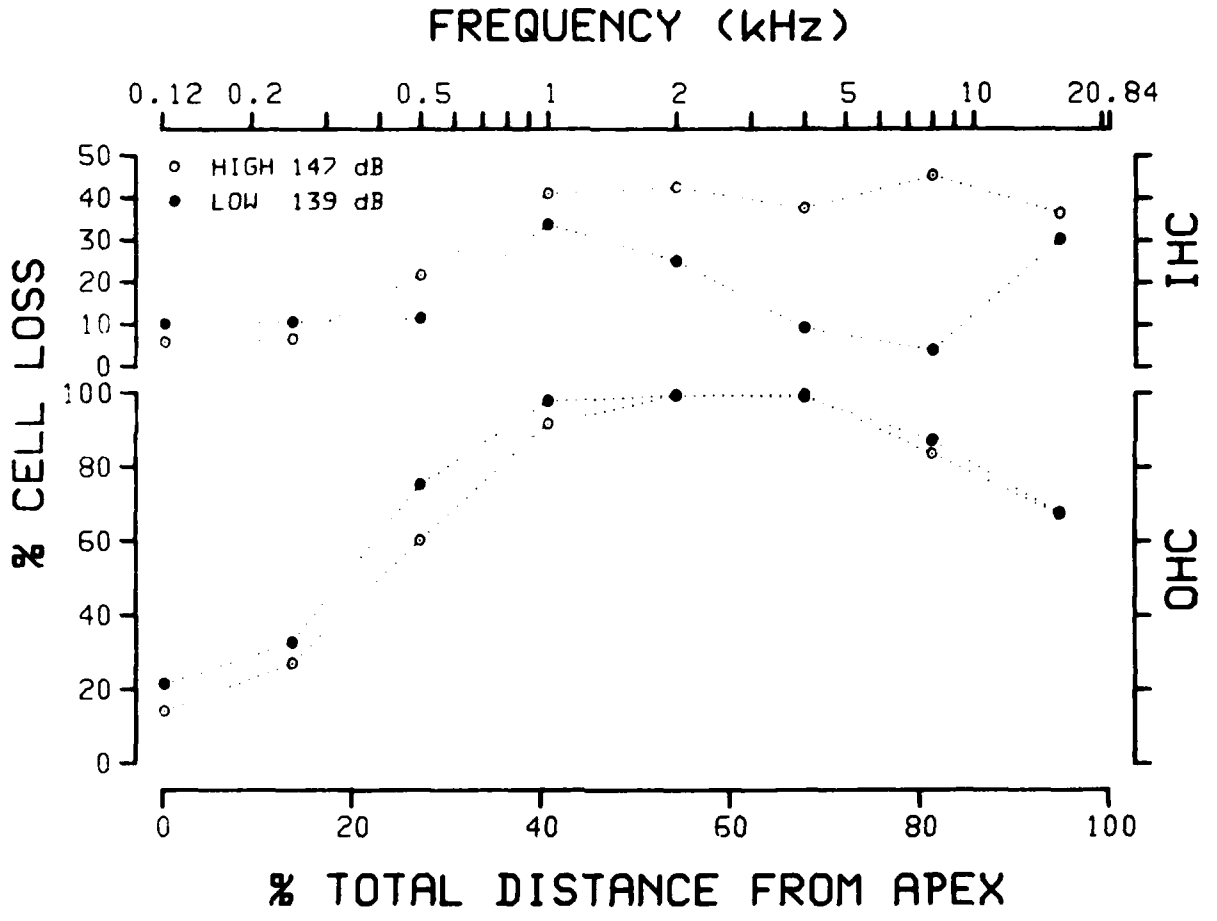


FIGURE 16. Group mean inner and outer hair cell losses computed over octave band lengths of the cochlea at the indicated frequencies for the 9.8 dB energy level exposure.

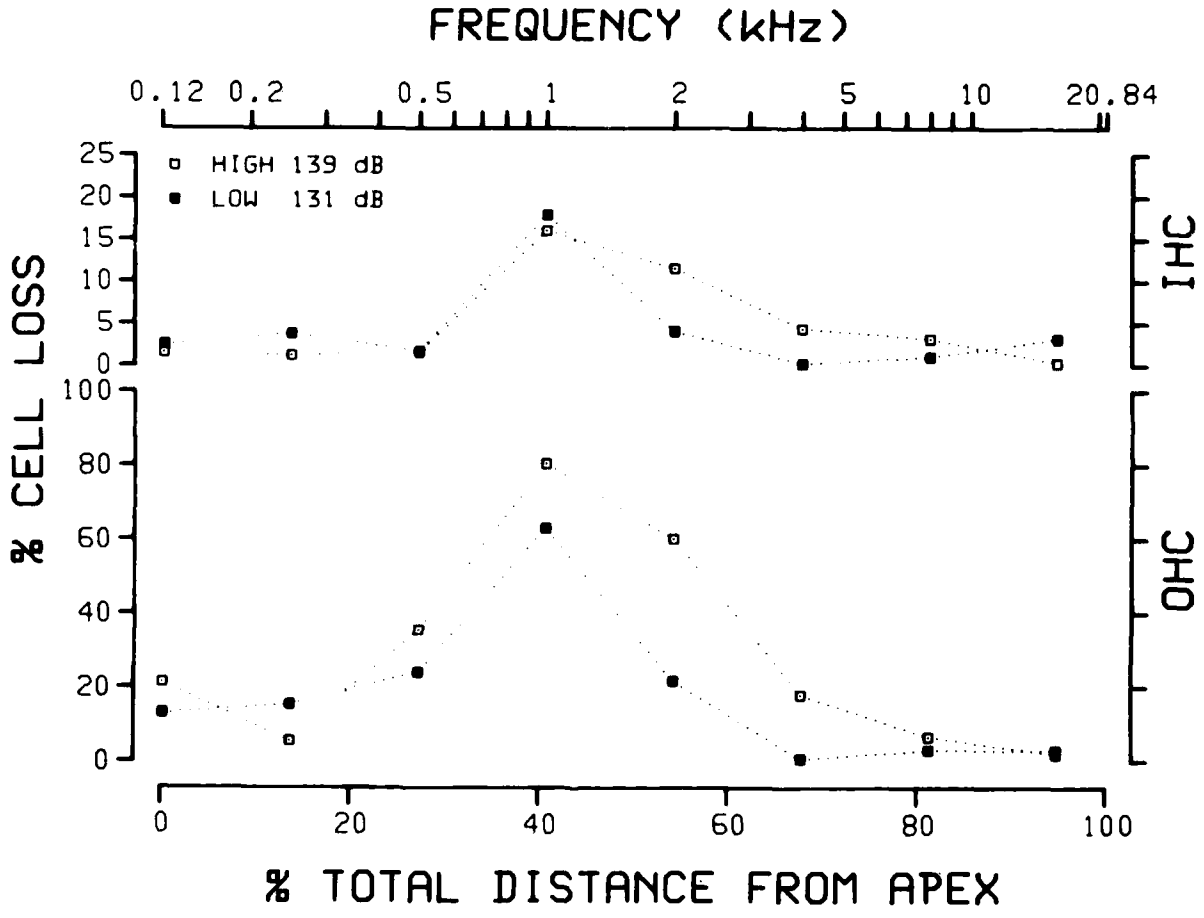


FIGURE 17. Group mean inner and outer hair cell losses computed over octave band lengths of the cochlea at the indicated frequencies for the 1.76 dB energy level exposure.

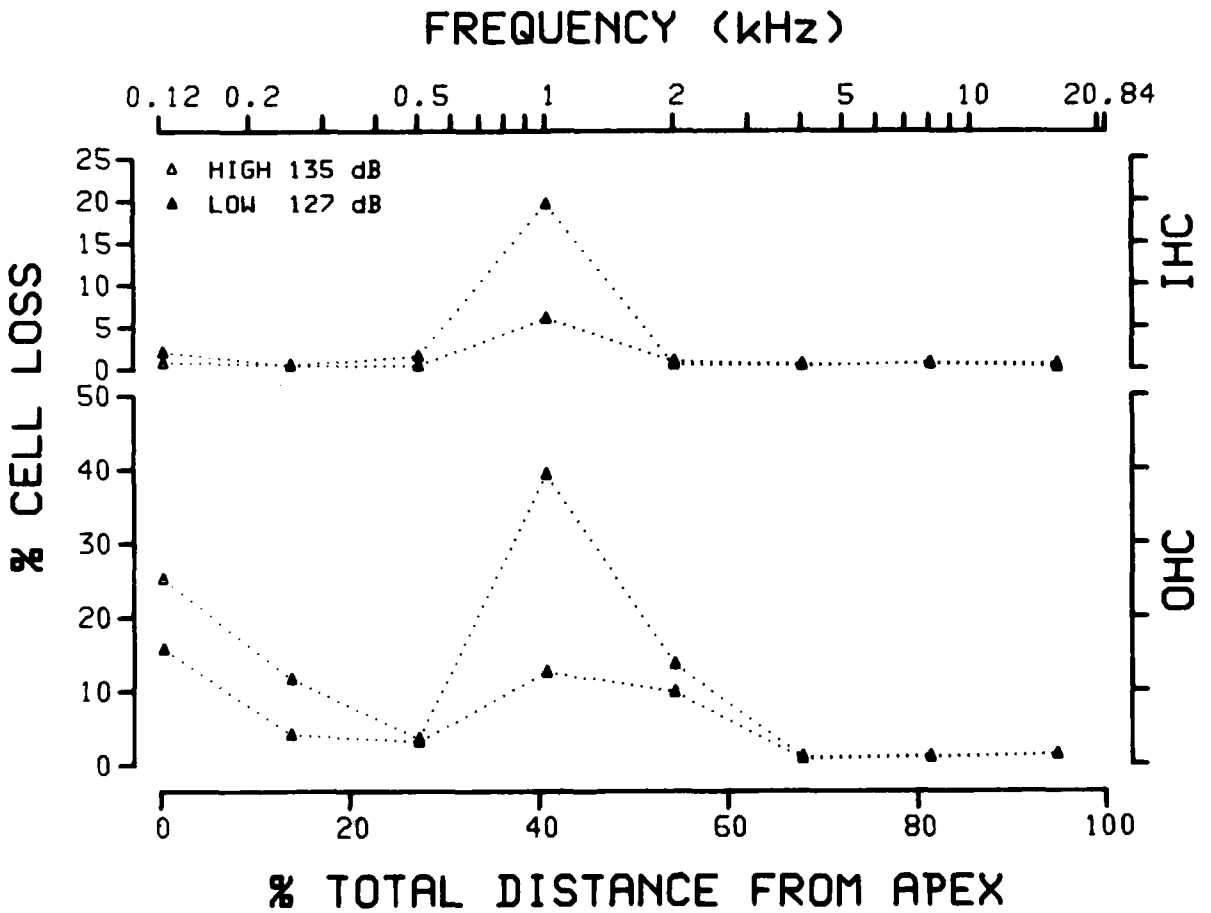


FIGURE 18. Group mean inner and outer hair cell losses computed over octave band lengths of the cochlea at the indicated frequencies for the -2.22 dB energy level exposure.

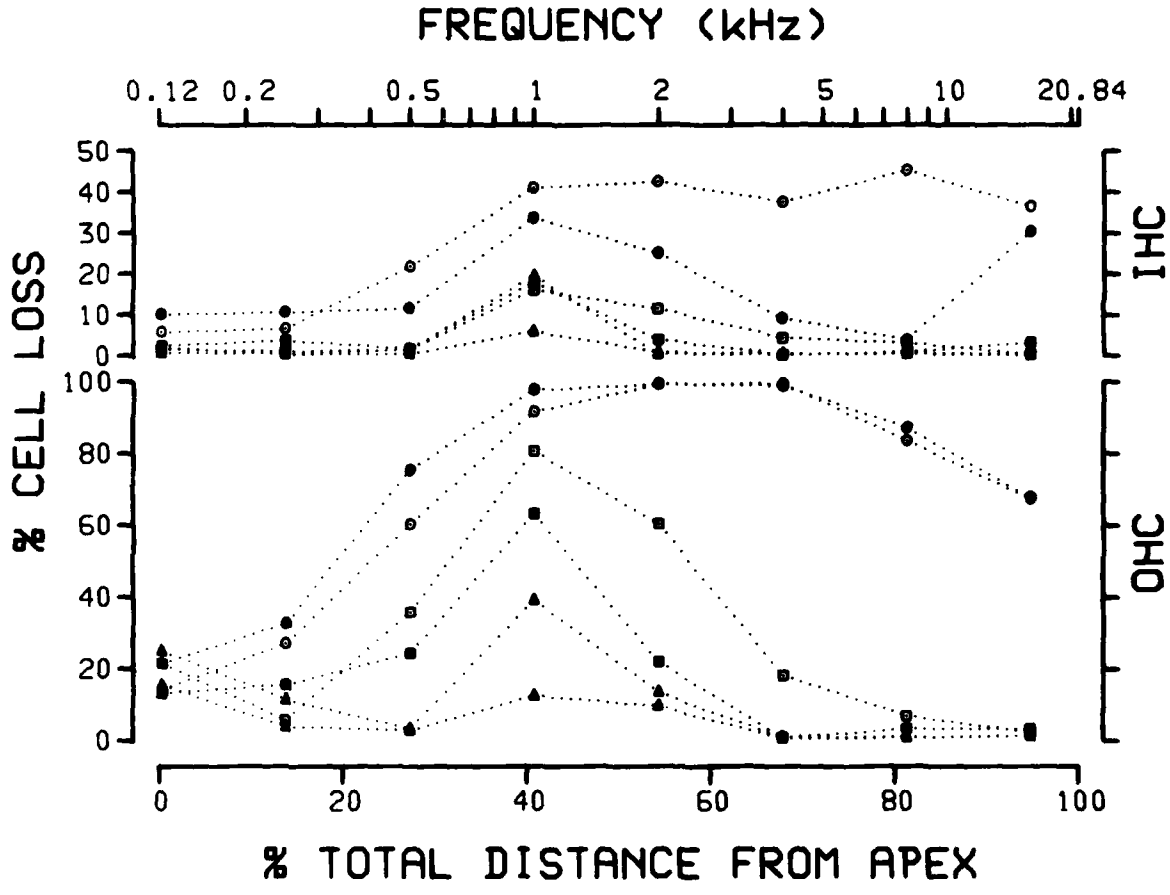


FIGURE 19. A comparison across all exposure energy levels of the inner and outer hair cell losses computed over octave band lengths of the cochlea at the indicated frequencies.

In general, the low peaked waves, for a given energy level of the exposure, consistently produced less sensory cell loss than did the high peaked waves. However, the standard deviations in the sensory cell mean data are large and this effect should be interpreted with caution.

The sensory cell loss in the Groups 3-6 shows a strong peak which is somewhat symmetric around the 1 kHz area; however, the PTS audiogram is relatively flat showing, for example, about a 20 dB hearing loss between 0.25 and 2 kHz in Group 3.

In order to establish the significance of the above observations, the inner and outer hair cell loss was subjected to an analysis of variance with energy level and wave type as the two primary treatment effects. Table 4 presents a summary of this analysis which indicates the effects of energy, test frequency, and the interaction of these two factors show significant effects in both inner and outer hair cell losses. In addition, wave type and the interaction between wave type and frequency and between wavetype, frequency, and energy are not significant.

A maximum hearing loss of about 40 dB is seen in the group exposed to the highest energy level (Group 1). This loss is relatively flat from 0.25 through 8.0 kHz. The mean sensory cell loss for these animals is very severe with a nearly complete loss of OHCs in the basal 70 percent of the cochlea, and 50 percent IHC losses throughout the basal one-half of the cochlea. Surprisingly, the low peaked Group 2 animals showed a much reduced loss of IHC compared to Group 1, while the final PTS audiograms for the two groups were quite similar.

An alternative way of presenting the sensory cell loss is shown in Figure 20. The total number of IHCs and OHCs that were missing in the entire cochlea were determined and then converted into a "dB-level" form, for direct comparison with PTS values. The data points in Figure 20 were obtained as follows: the total hair cell losses (either OHC or IHC) were found for each animal and the mean for the group determined. The average total number of OHCs and IHCs lost in an experimental group was referenced to 100 and 10 cells respectively and a dB level was computed according to the following:

$$dB(OHC)\ loss = 10 \log (OHC\ loss/100)$$

$$dB(IHC)\ loss = 10 \log (IHC\ loss/10)$$

The rationale for choosing the 100 OHC and 10 IHC cell reference was somewhat arbitrary, but can be justified by noting that a cochlea with losses of 100 OHCs and 10 IHCs scattered throughout the length of the cochlea could for all practical purposes be

TABLE 4 SUMMARY OF THE ANALYSIS OF VARIANCE ON SENSORY CELL LOSES

SUMMARY OF THE ANALYSIS OF VARIANCE FOR INNER HAIR CELL LOSS

TREATMENT	F	DF	P
Wave type	3.26	1/30	<0.10
Energy level	21.58	2/30	<0.001
Wave type by energy	1.87	2/30	>0.1
Test frequency	8.12	7/210	<0.001
Wave type by frequency	1.91	7/210	<0.07
Energy by frequency	2.36	12/210	<0.005
Wave type by energy by frequency	1.67	14/210	<0.07

SUMMARY OF THE ANALYSIS OF VARIANCE FOR OUTER HAIR CELL LOSS

TREATMENT	F	DF	P
Wave type	0.88	1/30	>0.1
Energy level	111.19	2/30	<0.001
Wave type by energy	1.84	2/30	>0.1
Test frequency	40.41	7/210	<0.001
Wave type by frequency	1.19	7/210	>0.1
Energy by frequency	17.72	14/210	<0.001
Wave type by energy by frequency	0.97	14/210	>0.1

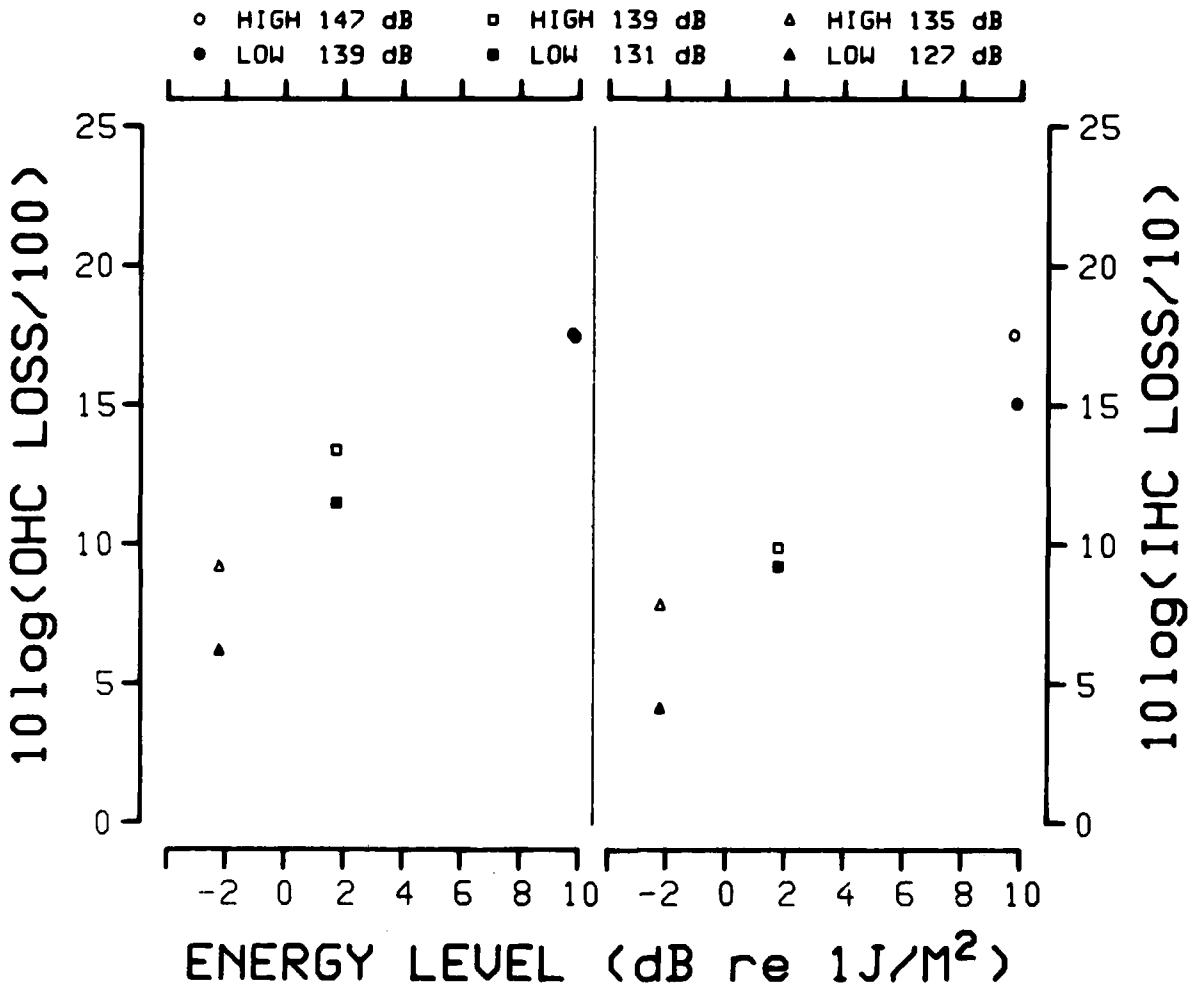


FIGURE 20. The group mean total number of inner and outer hair cells lost throughout the entire cochlea, expressed in dB, as a function of the energy level of the exposure.

considered a normal cochlea. This assumption breaks down if the sensory cell loss is concentrated in a very narrow region of the cochlea. However, in that case, the lesions would occupy less than 0.25mm of the cochlea and by our available psychoacoustic testing procedures could probably not be detected. When using these two reference figures to relate sensory cell loss on a dB scale, an average chinchilla cochlea devoid of all OHCs and IHCs would have approximately a 20 dB loss in each case.

Some interesting observations can be made from the sensory cell data as plotted in Figure 20, the shape of an "eye-fitted" curve would be relatively similar for both IHCs and OHCs. Both the IHC- and the OHC-loss functions appear to reach upper and lower asymptotes at similar energy levels, e.g., we can estimate by extrapolation that for 100 impulses presented at a rate of 1/3sec having a total energy of about -6 dB (re 1 J/M^2), the IHC and OHC losses will be negligible and thus the exposure will be safe. Similarly for an energy of more than 10 dB, the cochleas will sustain a near complete sensory cell loss.

Figure 21 illustrates the combined $\overline{PTS}$ 1,2,4 and the dB cell loss data plotted together. While this is a very "gross" method of viewing these data, it may have some predictive, or suggestive value. Consider that, although we are working over a limited range of parameters, we can estimate the "most likely" extent of sensory cell loss to be found associated with various levels of PTS. These data also point out that low levels of PTS, such as found from the lowest energy level exposure, can be deceptive, and that significant hair cell losses can in fact be present.

Figures 22 through 28 show surface preparation micrographs of the organ of Corti from various individual chinchillas in each of the six exposure conditions. These figures illustrate some of the features of the noise damaged organ of Corti that were, more or less, typical of each exposure condition. In general, the two highest energy exposures produced wide spread massive damage to the inner and outer sensory cells, supporting Deiter and Hensen cells, nerve fibers, etc. The remaining four exposure conditions generally produced more localized, punctate kinds of lesions. In all groups, the appearance of the lesioned organ of Corti exhibited a similar pattern: An area of severe loss in which the basilar membrane was devoid of sensory and supporting epithelial structures. The sensory epithelium was replaced by an irregular cuboidal epithelium (i.e., a reepithelization) bordered by regions of the organ of Corti whose structural elements are relatively intact and whose sensory cells show varying degrees of loss apical or basalward of the primary lesion. The following is a brief description of various features of the impulse noise induced lesions.

Groups 1 and 2: The massive lesions generated by exposure to the highest energy levels were similar in appearance and

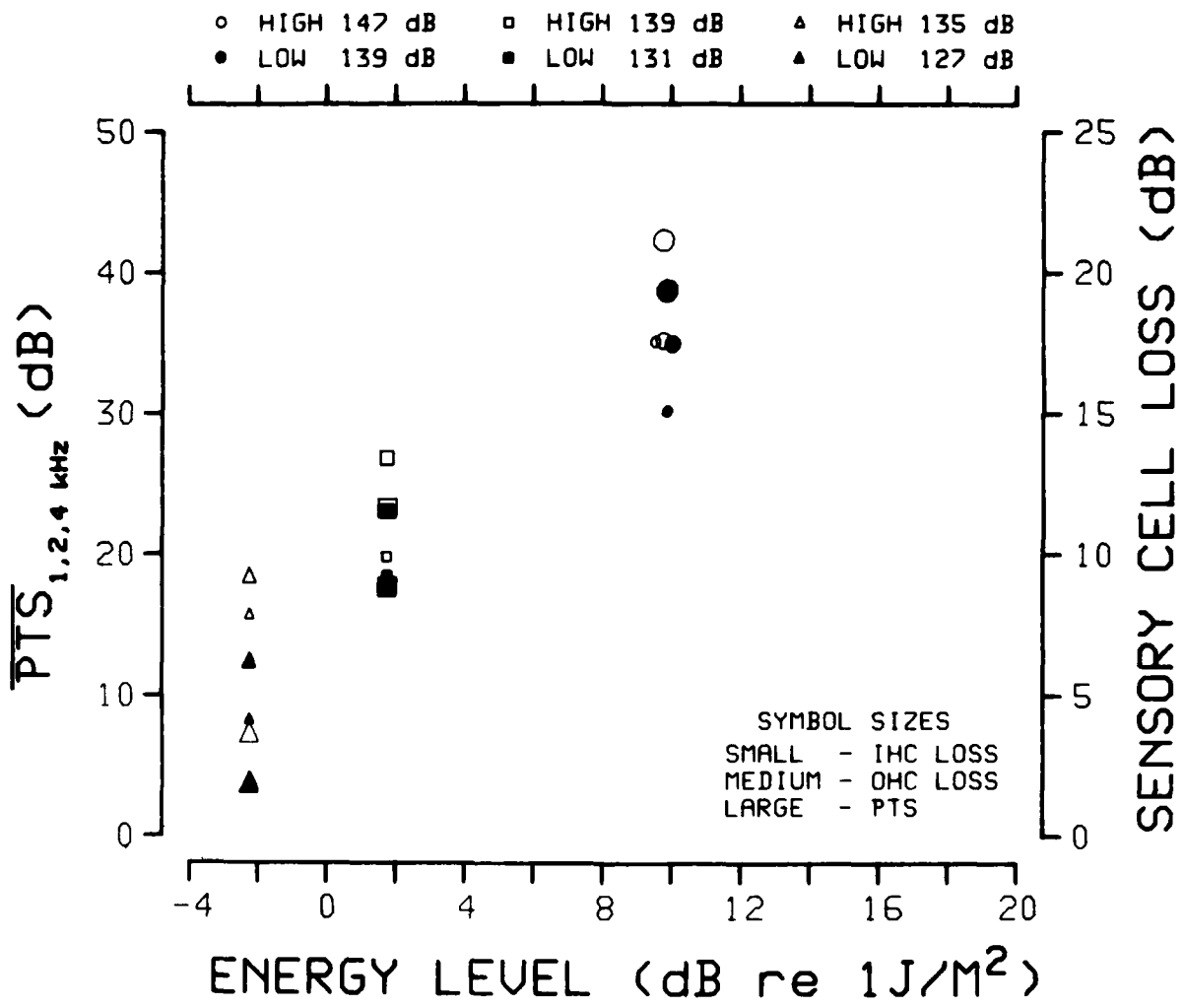


FIGURE 21. A comparison between the group mean total number of inner and outer hair cells lost and the mean PTS computed at 1, 2, and 4 kHz.

FIGURE 22. Surface preparation micrographs showing the region of impulse noise induced damage in the cochlea of animal G16. (Exposure: 139 dB low peak wave) Inset: low magnification view of the punctate lesion (L); arrow indicates a region of relatively normal organ of Corti.
A,C). Left and right edge of the lesion showing the abrupt transition from a normal appearing sensory epithelia to a complete loss of all epithelial structures on the basilar membrane.
B). Central area of the punctate lesion illustrating the reepithelialization of the basilar membrane (S) and the decrease in the number of myelinated nerve fibers (MNF). O; 1,2,3 - three rows of OHCs; P - Pillar cells; I - IHCs; H - Hensen Cells; ► missing OHCs, * - missing pillar cell.

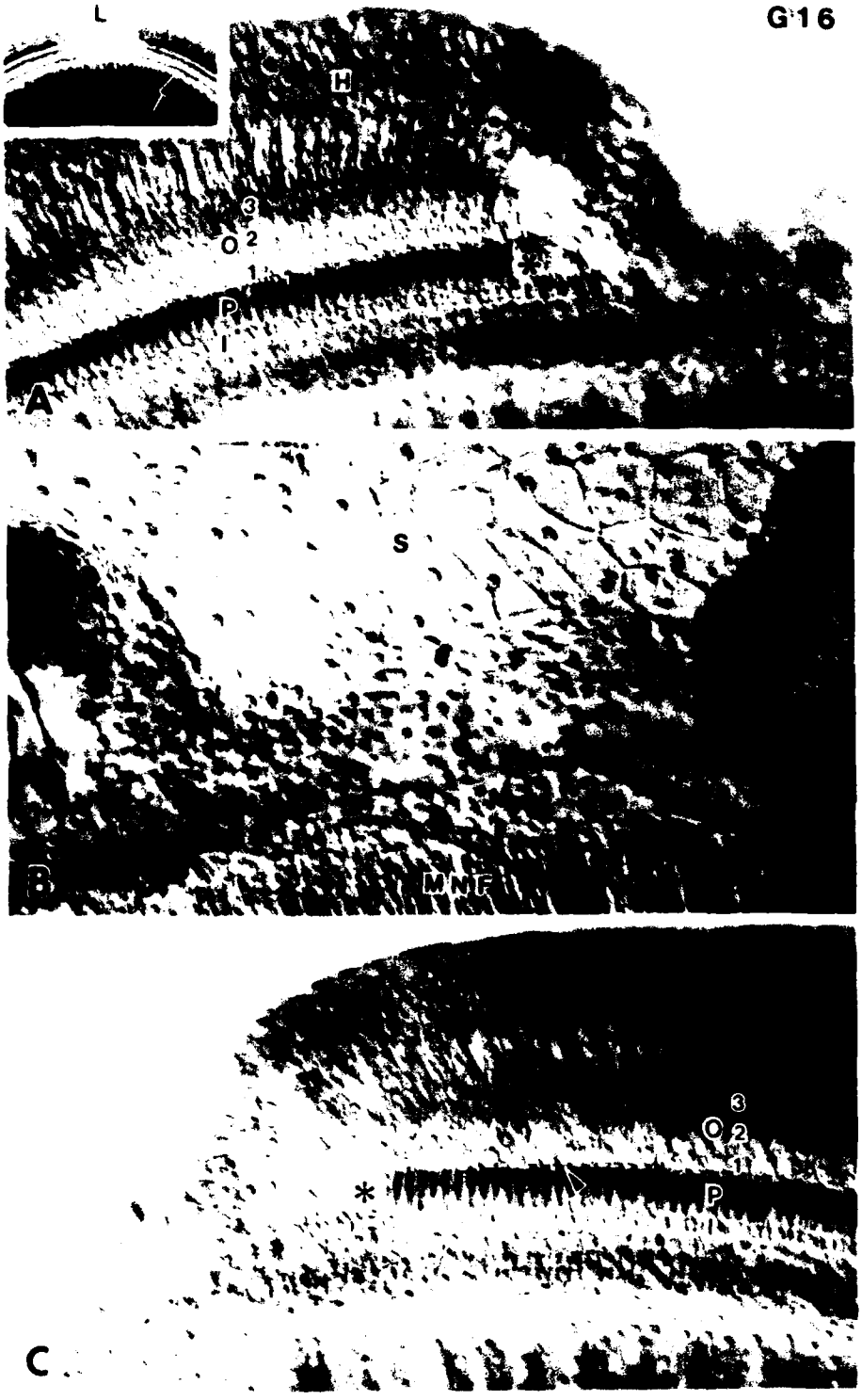

G16
L
H
3
O 2
1
P
I
A
S
B
MNF
3
O 2
1
P
C

FIGURE 23. A). Surface preparation micrograph from animal H32 (Exposure: 139 dB low peak wave) illustrating almost complete loss of OHCs (◄O►) and extensive loss of pillar cells (*).
B). Region of nearly complete loss of supporting cells and sensory cells in animal F24 (Exposure: 139 dB low peak wave) The inset shows a low magnification view of a large portion of the lesion. The arrow indicates the area illustrated in plate B.
C). An area basalward of the region shown in the inset from animal F24 illustrating an extensive loss of OHCs. In contrast, most of the IHCs in this specimen are present although out of focus. MNF - myelinated nerve fibers; I - IHCs.

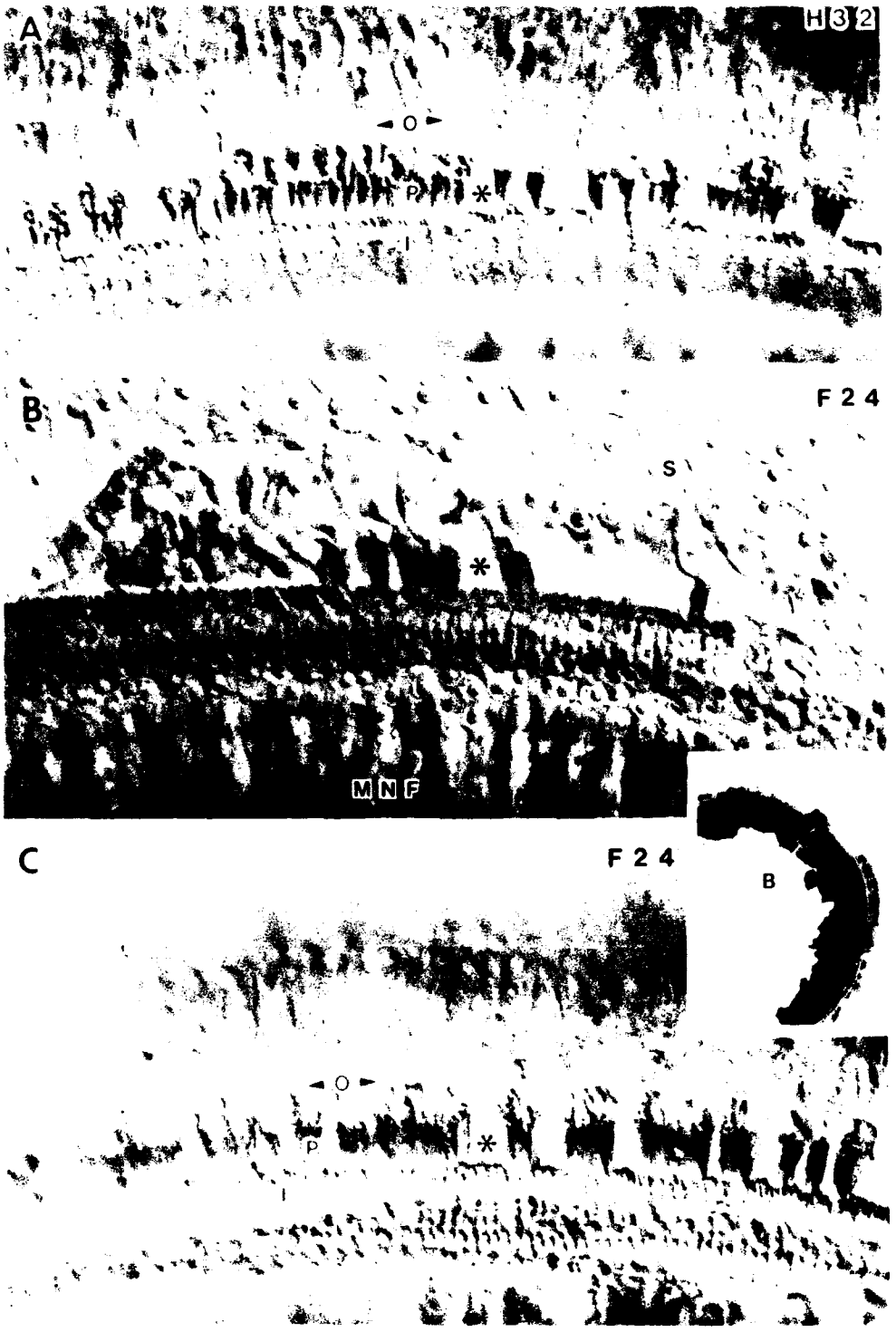

A
H 3 2
O
P
*
B
F 2 4
S
*
M N F
C
F 2 4
B
O
P
*

FIGURE 24. Surface preparation micrographs obtained from animal G20 (Exposure: 147 dB, high peak wave).
A). A focal lesion in the area of the Hensen cells (arrow), IHCs (I) generally are present, and many of the OHCs (O) also are present.
B). An edge of the main lesion shown in plates C and D illustrating the collapse of the Hensen cells.
C-D). Examples of the most severe type of damage where all the sensory and supporting elements on the basilar membrane are replaced by a simple epithelial layer (S). Note the reduction in myelinated nerve fibers (MNF). P-pillar cells; O-OHCs; I-IHCs; H-Hensen cells; S-scar tissue; ► missing OHC; *-missing pillar cells.

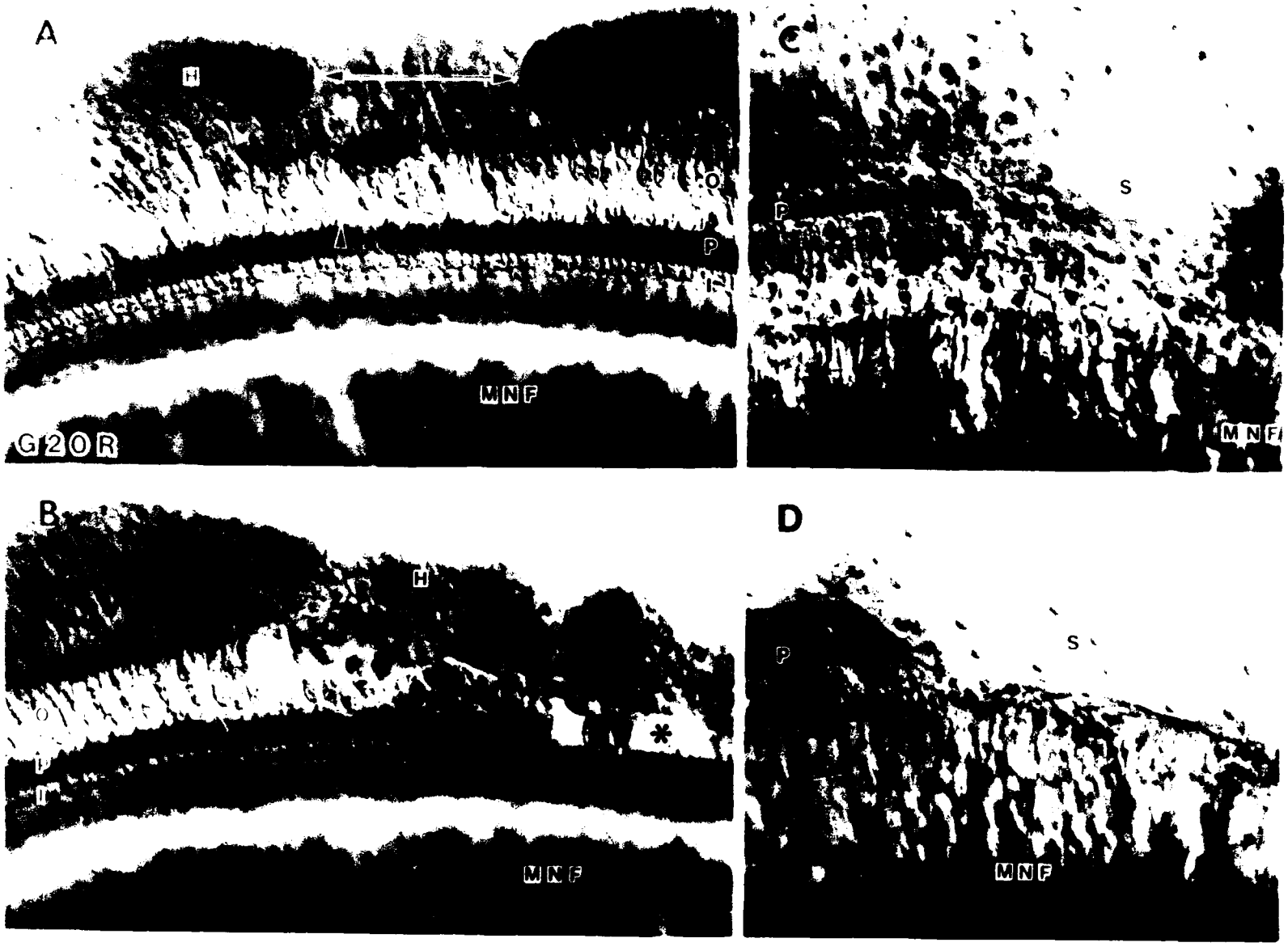

A
H
P
MNF
G20R
B
H
P
MNF
C
S
P
MNF
D
S
P
MNF

FIGURE 25. A). Surface preparation micrograph taken from the region indicated in the inset by the arrow. The lesion (L) is in the midcochlear region of animal H2 (Exposure: 131 dB low peak wave).
A). Extensive loss of OHCs (◄O►) and the subsequent union of Dieter cell heads.
B). Same specimen as shown in plate A, except that the plane of focus has been changed to illustrate the intact population of IHCs (I).
C). Punctate lesion (L) in the apical portion of the cochlea of animal F113 (Exposure: 131 dB low peak wave) s-scar tissue; a-artifact; MNF-myelinated nerve fiber; P-pillar cells.

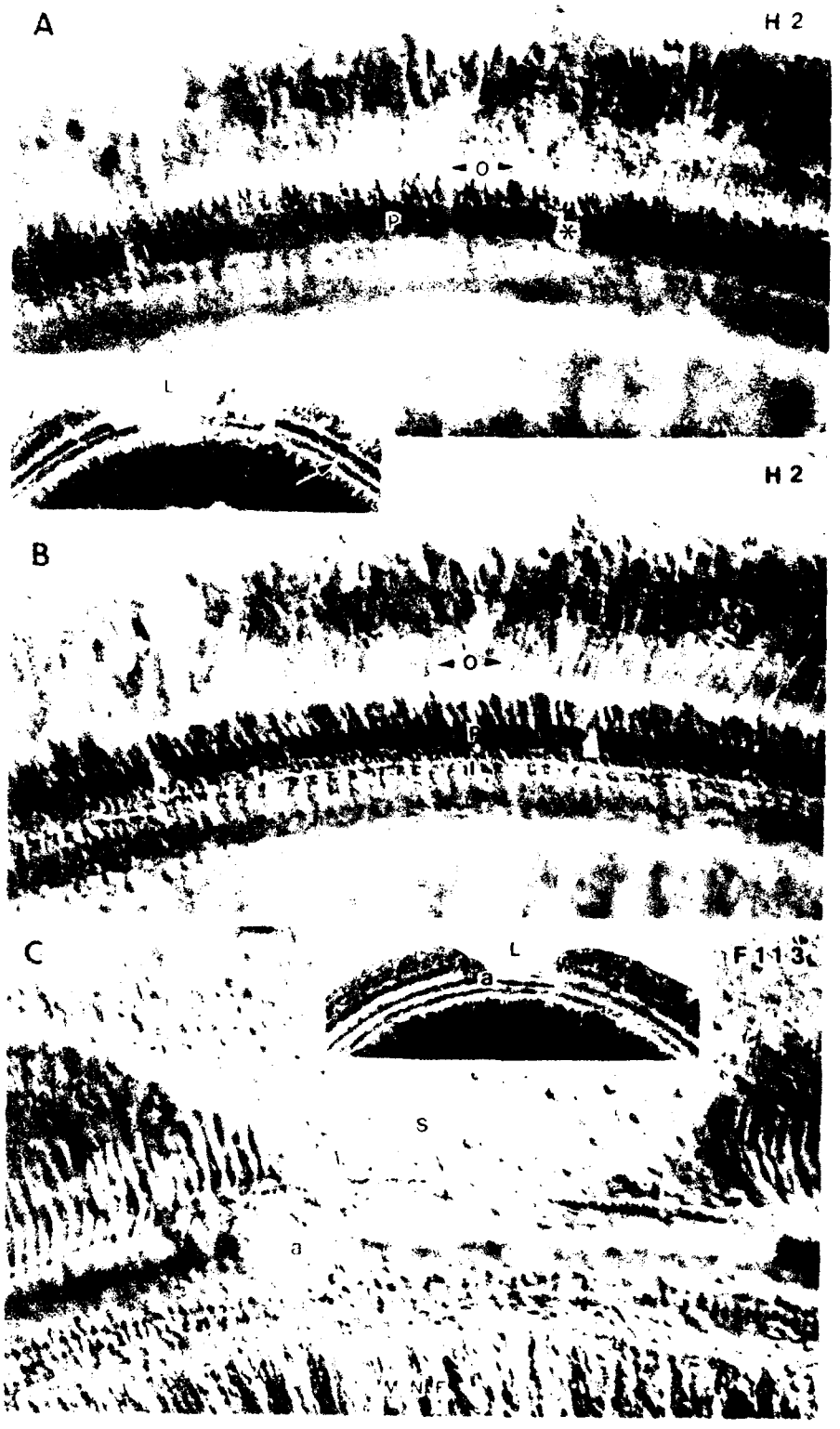

A
H 2
O
P
L
H 2
B
O
P
C
L
a
F 1 1 3
S
a

FIGURE 26. A, B). Right and left sides of the lesion illustrated in the inset from animal F2 (Exposure: 131 dB low peak wave). These plates illustrate the comparatively normal population of sensory cells up to the very edge of the lesion on the apical side (plate A) as opposed to the continuing loss of OHCs (◄O►) on the basal side of the lesion. C, D). Apical edge of the lesion from animal H2 (Exposure: 131 dB low peak wave). The pair of plates show the same specimen photographed at two different focal planes. Arrows indicate swollen OHCs. IHC (I) population is normal up to the very edge of the primary lesion at the extreme right of the micrograph. O;1,2,3-three rows of OHCs; *-pillar cell loss; L-lesion.

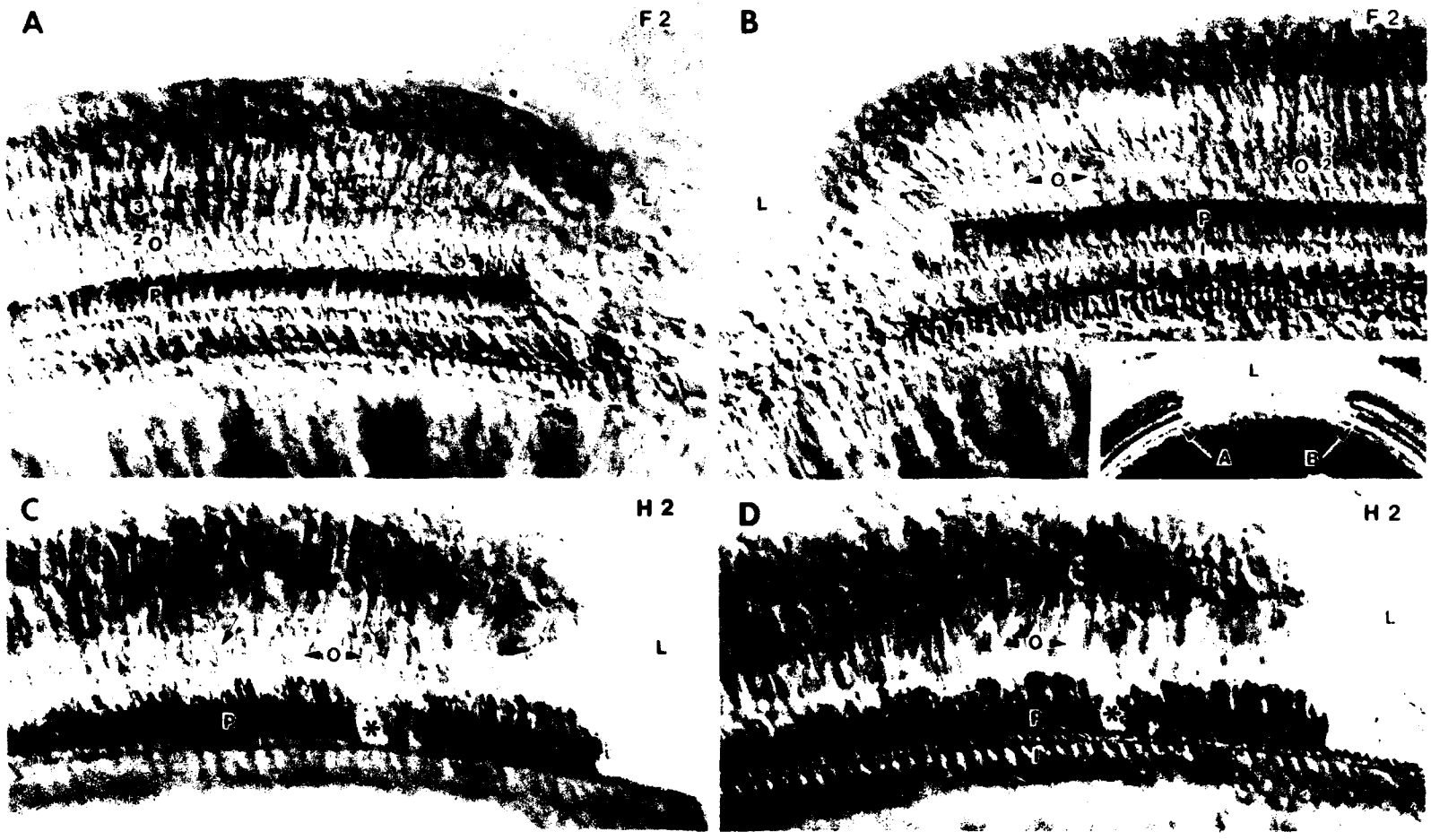

A
F 2
L
O
P
B
F 2
O
P
L
L
A
B
C
H 2
L
O
P
*
D
H 2
L
O
P
*

FIGURE 27. Three examples of the damaged organ of Corti taken from different areas of the cochlea of animal H16 (Exposure; 139 dB high peak wave). Note the general absence of OHCs in all three plates. H-Hensen cells; P-pillar cells; I-IHCs; MNF-myelinated nerve fibers; *-pillar cell loss; ► indicates scar tissue that has replaced damaged OHCs.

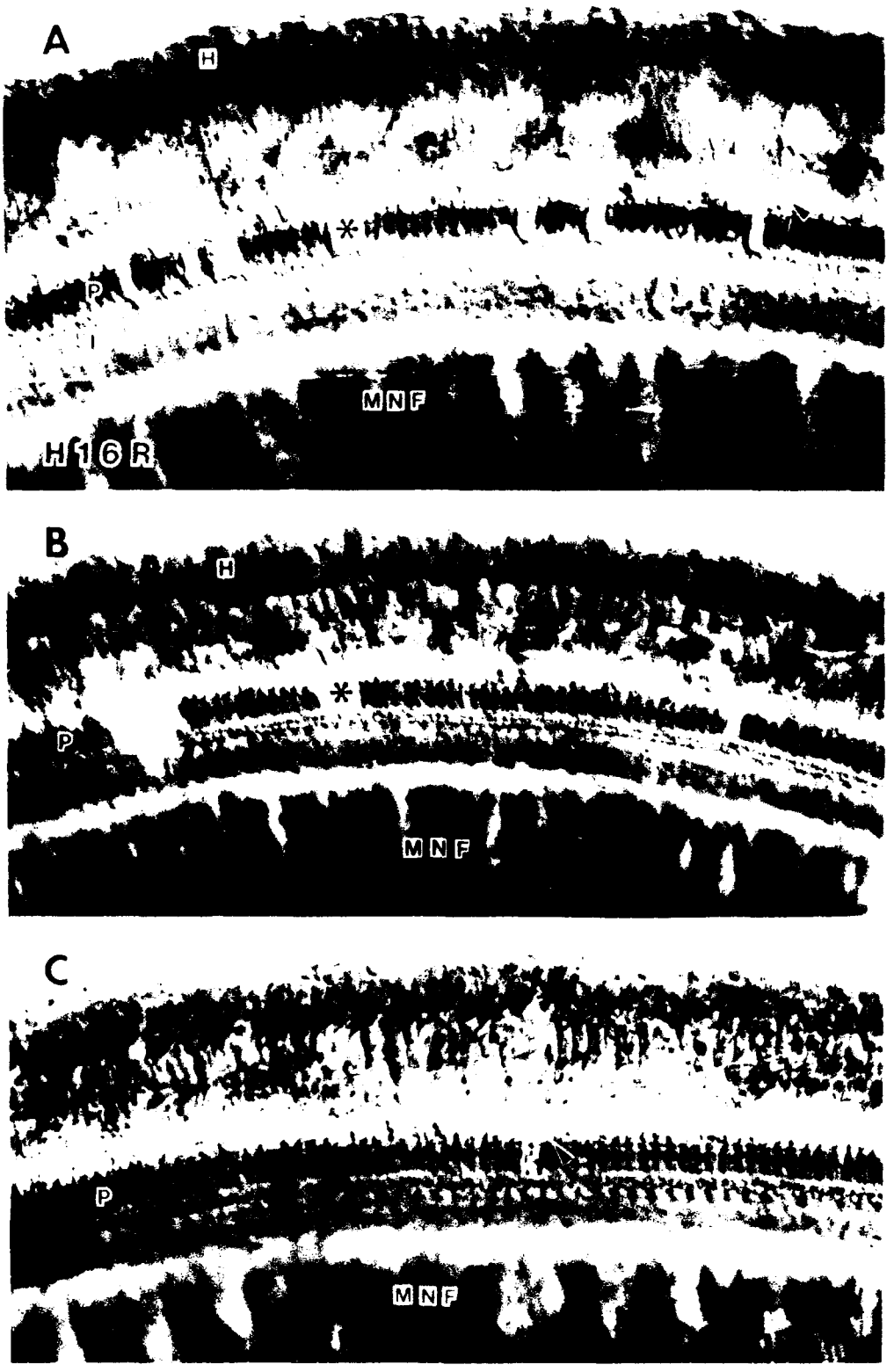
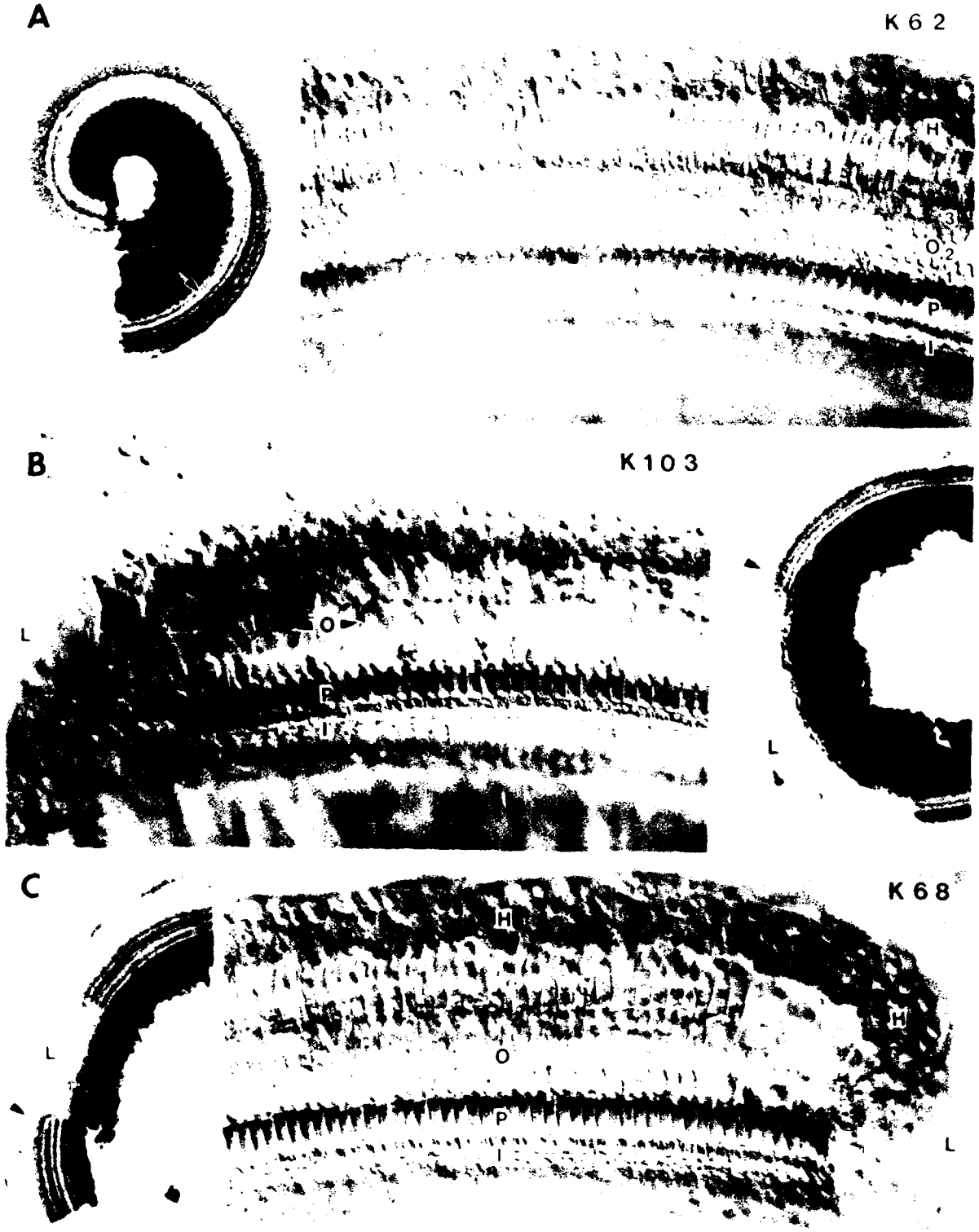

A
H
*
P
MNF
H16R
B
H
*
P
MNF
C
P
MNF

FIGURE 28. A). Normal appearing region of the cochlea from animal K68 (Exposure: 135 dB high peak wave) and a low magnification inset of the apex which shows relatively little sensory cell damage. Arrow indicates the area of the sensory cells. Note the regular appearance of the striations reflecting the location of the pillar cells and the sensory cells.
B, C). Micrographs of punctate lesions taken from the regions indicated in the insets from animals K103 and K68 (Exposure: 135 dB high peak wave) respectively. Although the animals are from the groups having the lowest energy of exposure, the basic appearance of the lesion is the same as that described in the previous micrographs.


A
K 6 2
H
3
O2
1.1
P
I
B
K 1 0 3
O
L
P
I
L
C
K 6 8
H
H
L
O
P
I
L

differed only, on the average, in the total numbers of sensory cells lost. The appearance of the damaged sensory epithelia is shown in Figures 22 through 24. The inserts in Figures 22 and 23 show two of the most frequently observed types of primary lesion: A restricted lesion in which the entire sensory epithelia is removed from the basilar membrane. There is generally a loss or reduction in the number of myelinated nerve fibers approaching the organ of Corti in that area (Figure 22 B) and the surface of the basilar membrane is covered with an irregular epithelial tissue which originates from the cells of the inner sulcus and from the area of the Claudius cells. Immediately adjacent to the lesion the sensory tissues may be relatively normal in appearance with surprisingly few sensory cells missing (Figures 22 A and C). Figures 22 A and C illustrate the edges of the lesion seen in the low magnification insert. Note the involvement of the Hensen cells in the formation of the edges of the lesion. The second and more extensive type of lesion is illustrated in Figure 23 (insert). In this figure, the lesion extends over several millimeters of the cochlea and there is an extensive loss of IHCs as well as OHCs throughout the area. The lesion is irregular in appearance because of the intermittent loss of supporting elements. In those areas devoid of supporting cells, the lesion appears similar to that previously described in Figure 22. In areas where there are considerable supporting cells remaining e.g., Figures 23 A and C, there are very few OHCs remaining and only the union of Deiter cell heads maintains the integrity of the reticular lamina. Generally, when inner pillar cells remain undamaged, the IHCs are present. If the lesion involves the inner pillar cells, as on the extreme right side of Figure 23 B, the IHCs are missing also. Figure 24 A illustrates an area of the organ of Corti where there is considerable, but not complete, OHC loss. However, an unusual lesion can be seen in the region of the Hensen cells. In this same animal both types of primary lesions described above can be found.

Groups 3 and 4: In general, the lesions in Groups 3 and 4 tend to be restricted to the midregions of the cochlea, i.e., in the 0.5 to 4.0 kHz areas. The most severe lesions were very punctate as illustrated in the inserts of Figures 25 and 26. The edges of the lesion from two different animals are seen in Figure 25 (insert). Their appearance, while more restricted, is similar to the lesions described for Groups 1 and 2. The sensory epithelium appears quite viable often up to the very edge of the primary lesion (Figures 26 A and B) in other cases, the sensory cell loss may spread in either the basal direction only, or in both the apical and basal directions. The sensory cell loss never was observed to spread only in the apical direction. This observation is in agreement with the mean sensory cell data presented in Figure 19. In some animals such as H16, (Figure 27) there are very few IHCs missing and there is not a primary focal lesion in the sense previously defined. In this situation,

(Figure 27 A) there are complete losses of OHCs and some supporting elements over several millimeters of the organ of Corti, and the reticular lamina is maintained by the fusion of the heads of the Deiter cells.

Groups 5 and 6: Most of the cochleas in these two groups showed comparatively little sensory cell loss and much of the organ of Corti (Figure 28) exhibits a uniform appearance typical of nonnoise exposed animals. At higher magnification (Figure 28 A), the regular arrangement of the OHCs and IHCs can be visualized easily. In those animals with lesions, e.g., Figures 28 B and C, the lesion appeared basically the same as in any of the preceeding groups, and usually occurred in the 1 to 2 kHz area of the cochlea.

In summary, there is a consistent pattern to the lesion produced by the noise impulses used in these experiments. The lesion begins to make its appearance in the 1 to 2 kHz region of the cochlea, and can be very punctate in nature involving all the epithelial cells on the basilar membrane between the inner and the outer sulcus. Two primary types of lesions differing primarily in the magnitude or extent of the lesion have been defined. Associated with these primary lesions there are usually OHC losses scattered apical or basalward. The Hensen cells are involved in the formation of the edges of the lesion, and the focal areas of the lesion are usually covered by cells originating in the area of the Claudius cells and the cells of the inner sulcus. IHCs tend to be missing most frequently when the inner pillar cells have been damaged.

There is a very limited amount of data in the literature to which the results of this study may be compared. The most revalent data have recently been published by Roberto, et al. (1985). They exposed chinchillas to impulse noise having a spectrum which was fairly broad with a peak around 1 kHz. The impulse had an overall B-duration of approximately 200 ms. Four groups of animals were exposed at peak pressure levels of 107, 113, 119, and 125 dB SPL. The repetition rate was kept constant at 4 impulses/s. To maintain an equal total energy of exposure, the duration of the exposure was varied from 120 h to 1.87 h. Thus this experimental design can be used to test the validity of the equal energy hypothesis over a limited range of parameters and to obtain a perspective on the role of peak pressure in the production of acoustic trauma. Roberto, et al. found that when TTSmax was used as an index of trauma, TTSmax increased with increasing peak pressure even though the total energy of the exposure remained constant. However, when the group mean PTS data and sensory cell losses were used as an index of trauma, the three lowest peak SPL exposures produced the same effect, i.e., approximately the same PTS as well as sensory cell loss. On the other hand, the 125 dB exposure produced as much as 30-40 dB more

PTS and much greater sensory cell loss. Thus it would appear that in this experimental design there is a critical intensity below which the peak of the impulse is not the primary determinant of trauma, but above which trauma is very acutely related to peak pressure.

There are substantial differences in the experimental paradigms between the Roberto, et al. experiment and that reported here, and clear generalizations cannot be made. However, there are clear indications in both of these experiments that under some conditions peak pressure can be the primary determinant of trauma while under another set of exposure conditions energy has the greatest influence on the amount of trauma. Until a sufficient number of conditions have been tested, the respective roles of peak pressure and energy in producing acoustic trauma cannot be established with any certainty.

CONCLUSIONS

The threshold shift measured within the first few hours after exposure showed a systematic variation with both peak pressure and energy level. The permanent threshold shift measured 20 to 30 days postexposure, and the loss of sensory cells showed a strong dependence on energy level with a less pronounced dependence on peak pressure. These results indicate that peak pressure is not a sufficient indicator of auditory hazard; however, energy alone is not a sufficient indicator either.

REFERENCES

Burdick, C. K., Patterson, J. H., Mozo, B. T., and Camp, R. T. 1978. Threshold shifts in chinchillas exposed to octave bands of noise centered at 63 and 1000 Hz for three days. The Journal of the the Acoustical Society of America. 64:458:466.

CHABA. 1968. Committee on hearing and bioacoustics. Proposed damage risk criterion for impulse noise (gunfire). Report of Working Group 57, NAS-NRC, Washington, DC.

Dancer, A., 1984. Personal Communication. NATO Panel VIII/RSG 6 Meeting, Meppen, Germany.

Department of the Army. 1972. Noise and conservation on hearing. Fort Monroe, VA.: Department of the Army. TB-MED-501.

Department of Defense. 1975. Noise limits for Army material. Washington, DC: Department of Defense. MIL-STD-1474B(MI).

Eldredge, D. H., Miller, J.D., Bohne, B. A., and Clark, W. W. 1977. Frequency-position map for the chinchilla cochlea. The Journal of the Acoustical Society of America. 62:(S1)S35.

Engstrom, H., Ades, H. W., and Anderson, A. 1966. Structural Pattern of the Organ of Corti. Almquist and Wiksell, Stockholm, Sweden.

Forrest, M.F., 1984. Personal Communication. NATO Panel VIII/RSG 6 Meeting, Meppen, Germany.

Henderson, D. and Hamernik, R. P. 1982. Asymptotic threshold shift from impulse noise. In: New Perspectives on Noise-Induced Hearing Loss, eds., R. P. Hamernik, D. Henderson, R. Salvi, Raven Press, NY, 265-281.

Luz, G.A. and Hodge, D. C. 1971. The recovery from impulse noise-induced TTS in monkeys and men: A descriptive model. The Journal of the Acoustical Society of America. 49:1770-1777.

Miller, J. D. 1970. Audibility curve of the chinchilla. The Journal of the Acoustical Society of America. 48:513-523.

Patterson, J. H. and Green, D. M. 1970. Discrimination of transient signals having identical energy spectra. The Journal of the Acoustical Society of America. 48:894-905.

Pfander, F. 1975. Das knalltrauma. Springer-Verlag, Berlin.

Pfander, F., Bongartz, H., Brinkman, H., and Kietz, H. 1980. Danger of auditory impairment from impulse noise: A comparative study of the CHABA damage-risk criteria and those of the Federal Republic of Germany. The Journal of the Acoustical Society of America. 67:628-633.

Roberto, M., Hamernik, R. P., Salvi, R. J., Henderson, D. and Milone, R. 1985. Impact noise and the equal energy hypothesis. The Journal of the Acoustical Society of America. 77:1514-1520.

Smoorenburg, G.F. 1982. Damage risk criteria for impulse noise. In: New Perspectives on noise-induced hearing loss, eds. R. P. Hamernik, D. Henderson, and R. J. Salvi. Raven Press, NY, 471-490.

Winer, B. J. 1971. Statistical Principals in Experimental Design. McGraw-Hill Book Company, NY, 907.

APPENDIXES

APPENDIX A

Preexposure baseline audiograms for each animal used in this study. The individual animals are arranged by exposure groups*.

Two types of summary audiograms are presented:

(a) Mean baseline audiograms for each of the six exposure groups, and

(b) A single mean audiogram for all the animals (N=36) used in this study.

The standard deviation (SD) for each mean measure is also presented.

*The exposure groups are identified as follows:

Group 1 - 147 dB peak SPL; 0.095 J/M^2, high peak impulse

Group 2 - 139 dB peak SPL; 0.097 J/M^2, low peak impulse

Group 3 - 139 dB peak SPL; 0.015 J/M^2, high peak impulse

Group 4 - 131 dB peak SPL; 0.015 J/M^2, low peak impulse

Group 5 - 135 dB peak SPL; 0.006 J/M^2, high peak impulse

Group 6 - 127 dB peak SPL; 0.006 J/M^2, low peak impulse

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (1) 147 dB peak SPL; 0.095 J/M^2, high peak impulse

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
G5	X	23	8	2	4	2	5	1	5	5	5
	SD	6.6	4.3	3.9	2.8	3.9	5.1	3.2	0.7	4.2	4.2
G20	X	25	12	2	3	3	4	1	4	4	4
	SD	2.4	5.9	5.0	4.4	7.5	4.4	8.6	7.1	5.4	5.1
G2	X	24	4	3	1	5	6	6	4	2	9
	SD	1.6	1.6	4.2	3.5	4.2	4.2	4.7	1.6	5.7	1.6
E138	X	18	9	1	-3	1	8	-	9	9	10
	SD	5.8	7.8	0.5	4.8	4.8	0.5	-	2.8	7.2	5.6
F1	X	19	7	0	-2	2	7	-	-1	5	8
	SD	1.6	4.8	3.5	1.6	3.5	1.6	-	1.6	3.5	4.2
E115	X	25	5	0	-2	3	5	-	0	2	0
	SD	4.0	5.4	1.8	6.0	3.2	5.5	-	3.7	2.6	4.4
	GM*	22.3	5.8	1.2	0.2	2.7	5.8	-	3.5	4.5	6.0
	SD	3.1	2.6	1.2	2.9	1.4	1.5	-	3.6	2.6	3.7

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (2) 139 dB peak SPL; 0.097 J/M^2, low peak impulse

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
E17	X	21	12	6	1	-2	7	-	4	5	4
	SD	3.2	4.1	3.5	3.4	2.8	9.2	-	6.1	5.3	4.9
F12	X	19	9	2	4	4	9	-	8	7	12
	SD	6.5	2.3	1.6	4.7	1.6	4.7	-	6.3	5.2	3.5
F24	X	21	10	1	-1	-1	2	-	8	5	9
	SD	2.8	3.3	0.4	5.8	0.4	5.8	-	2.8	3.3	5.5
F120	X	21	5	4	2	6	5	7	1	5	4
	SD	1.6	4.2	1.6	3.5	1.6	4.2	1.6	1.6	1.6	3.1
H32	X	23	11	2	1	-1	0	2	4	3	9
	SD	4.5	4.8	5.4	5.4	4.0	3.9	6.0	6.4	6.9	3.7
G16	X	26	10	4	5	5	3	2	7	4	6
	SD	4.1	3.1	5.9	3.8	1.6	4.1	4.1	2.7	3.7	5.6
	GM*	21.8	9.5	3.2	2.0	1.8	4.3	-	5.3	4.8	5.7
	SD	2.4	2.4	1.8	2.2	3.5	3.3	-	2.8	1.3	2.9

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (3) 139 dB peak SPL; 0.015 J/M^2, high peak impulse

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
E109	X	14	13	6	1	2	7	-	10	8	10
	SD	3.6	5.2	1.5	5.0	4.5	2.2	-	3.5	4.9	0.4
G30	X	24	7	6	-5	-2	2	0	-1	4	-1
	SD	4.6	3.3	3.9	4.9	4.0	3.0	4.3	5.1	8.8	4.0
E144	X	22	12	5	1	1	6	-	12	8	7
	SD	1.7	1.3	1.1	1.7	4.4	2.9	-	1.3	1.6	1.3
H16	X	24	11	-3	-3	3	4	1	3	2	4
	SD	3.6	0.9	3.1	6.9	4.8	3.1	3.4	7.4	1.5	4.3
H1	X	27	5	5	4	4	3	2	6	8	8
	SD	1.6	4.4	4.1	4.2	1.6	2.2	1.6	3.3	4.1	3.6
H42	X	23	4	-5	-4	-5	3	0	0	0	2
	SD	4.8	4.1	3.1	4.7	6.1	6.3	4.4	5.2	8.2	1.5
	GM*	22.3	8.7	1.5	-1.0	0.7	4.2		5.0	3.5	5.0
	SD	4.4	3.8	4.6	3.5	3.3	1.9		5.3	3.5	4.1

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (4) 131 dB peak SPL; 0.015 J/M^2, low peak impulse

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
D22	X	17	15	3	0	3	5	-	3	7	9
	SD	6.1	4.0	3.3	4.0	3.9	4.7	-	1.9	8.0	1.3
F113	X	27	9	3	2	3	3	-	3	7	5
	SD	5.2	6.8	4.6	3.4	7.2	5.8	-	5.4	7.2	1.3
F2	X	23	4	4	1	-1	3	-	2	10	7
	SD	1.7	3.2	4.0	1.6	3.5	3.1	-	1.5	5.8	1.5
H12	X	28	9	7	-4	-5	2	0	3	4	3
	SD	5.9	7.0	7.3	5.1	1.8	4.6	3.7	9.6	5.3	7.5
H2	X	27	8	1	1	2	10	4	5	8	6
	SD	1.6	3.2	3.8	3.2	2.7	3.3	4.1	3.4	3.1	3.0
G9	X	21	10	0	-1	0	6	3	2	-4	1
	SD	4.9	3.1	2.5	4.2	5.1	1.5	6.2	4.2	4.0	4.2
	GM*	23.8	9.2	3.0	-0.2	0.3	4.8	-	3.0	5.3	5.2
	SD	4.3	3.5	2.4	2.1	3.1	2.9	-	1.1	5.0	2.9

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (5) 135 dB peak SPL; 0.006 J/M^2, high peak impulse

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
G21	X	26	9	4	1	1	3	3	-2	-1	8
	SD	5.0	3.0	4.4	2.3	3.3	6.4	8.2	5.9	3.3	2.3
K68	X	24	12	3	2	2	2	3	5	4	9
	SD	2.9	4.1	2.2	4.7	3.6	3.6	3.6	2.2	2.2	7.5
K103	X	32	8	-5	2	-4	-2	2	-1	4	3
	SD	1.4	5.5	6.0	2.7	5.4	5.2	7.6	4.2	6.1	7.2
K108	X	24	12	-5	-2	2	4	4	3	0	1
	SD	5.0	3.0	3.3	5.9	3.4	3.8	3.8	3.8	4.7	4.7
K116	X	20	10	5	4	0	2	6	1	2	1
	SD	3.2	4.5	3.2	3.2	4.5	3.2	3.2	4.5	3.2	3.2
H184	X	18	10	-3	6	0	4	2	3	2	3
	SD	3.0	3.0	2.7	3.6	2.7	4.3	3.2	3.6	4.3	3.6
	GM*	24.0	10.2	-0.2	2.2	0.2	2.2	3.0	1.5	1.8	4.2
	SD	4.9	1.6	4.7	2.7	2.2	2.2	1.8	2.7	2.0	3.5

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAMS (dB SPL) AND STANDARD DEVIATION (dB)

Group (6) 127 dB peak SPL; 0.006 J/M^2, low peak impulse

		Test Frequency (kHz)									
Animal #		.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
K62	X	21	11	2	1	3	3	1	2	3	2
	SD	3.3	3.6	2.6	3.6	3.0	3.0	3.3	5.4	2.6	3.0
K115	X	29	9	2	5	3	1	5	2	-1	6
	SD	7.6	6.4	4.9	6.9	7.6	7.4	7.7	6.9	9.2	5.6
K69	X	18	12	1	2	1	2	2	3	0	3
	SD	3.6	2.4	4.7	2.4	2.9	4.3	3.0	3.4	3.0	3.4
K114	X	23	11	4	3	-1	3	1	3	1	3
	SD	4.5	3.2	3.2	3.6	5.5	5.2	2.7	2.3	5.5	2.3
K102	X	20	10	-1	0	0	2	0	-3	0	1
	SD	2.3	3.0	4.6	5.4	2.3	3.3	5.0	3.0	4.6	4.6
K93	X	24	10	0	2	4	0	2	4	0	6
	SD	7.4	5.5	4.9	3.0	3.8	4.3	6.1	4.0	2.6	3.6
	GM*	22.5	10.5	1.3	2.2	1.7	1.8	1.8	1.8	0.5	3.5
	SD	3.8	1.0	1.8	1.7	2.0	1.2	1.7	2.5	1.4	2.1

*GM = Group Mean

PREEXPOSURE BASELINE AUDIOGRAM (dB SPL) AND STANDARD DEVIATION (dB) FOR ALL ANIMALS USED IN THIS STUDY

	Test Frequency (kHz)									
Group Means	.125	.25	.5	1.0	1.4	2.0	2.8	4.0	5.7	8.0
1	22.3	5.8	1.2	0.2	2.7	5.8	-	3.5	4.5	6.0
2	21.8	9.5	3.2	2.0	1.8	4.3	-	5.3	4.8	5.7
3	22.3	8.7	1.5	-1.0	0.7	4.2	-	5.0	3.5	5.0
4	23.8	9.2	3.0	-0.2	0.3	4.8	-	3.0	5.3	5.2
5	24.0	10.2	-0.2	2.2	0.2	2.2	3.0	1.5	1.8	4.2
6	22.5	10.5	1.3	2.2	1.7	1.8	1.8	1.8	0.5	3.5
Mean	22.8	9.0	1.7	0.9	1.2	3.9	-	2.5	3.5	4.9
SD	0.9	1.7	1.3	1.4	1.0	1.5	-	1.7	1.8	0.9

APPENDIX B

Postexposure threshold shifts for each exposure group (1-6) and for individual animals in each group.

Permanent threshold shift (PTS) is the mean of the threshold shifts otained on the last four postexposure days.

Average maximum threshold shift (TS) is calculated by taking the maximum threshold shift for each animal, irrespective of when in time it occurred, and averaging the maximum TS across the animals that constitute the particular exposure group.

Standard Deviation (SD) for all measures are presented when appropriate.

Group 1 - Postexposure Threshold Shifts

Animals:	E115R*
	F1R
	E138R
	G2R
	G20R
	G5R

*R refers to the right ear

GROUP 1

GROUP MEAN POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: High peak 147 dB; 100 Impulses; 0.095 J/M^2/impulse

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
58	78	77	76	80	81		69	63	54	0.000
57	59	72	70	72	70		60	68	53	0.021
45	60	69	74	76	75		69	66	53	0.042
52	67	80	82	83	75		70	65	55	0.063
59	67	82	83	84	81		67	72	55	0.125
58	64	76	81	77	82		69	67	53	0.250
51	63	79	80	76	71		60	68	55	1.000
48	55	71	66	67	66		51	56	50	2.000
39	51	61	55	56	58		48	47	41	6.000
30	48	52	56	55	52		44	42	38	9.000
30	44	44	50	49	51		37	42	34	13.000
25	41	43	49	49	45		41	42	38	16.000
26	36	44	47	50	41		42	38	35	20.000
25	41	46	41	47	43		41	38	38	23.000
24	35	33	42	46	49		37	32	39	27.000
21	34	33	49	43	40		37	40	36	30.000
24	37	39	45	46	43		39	37	37	MEAN GROUP PTS (dB)
8.4	7.0	6.2	2.6	6.6	4.4		3.0	4.9	5.6	SD GROUP PTS (dB)
71	80	89	87	89	88		75	79	64	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
14.3	12.9	6.0	8.7	11.6	18.7		5.4	14.2	11.3	0.000
14.2	10.6	10.0	6.8	9.0	9.0		11.8	6.9	10.6	0.021
7.8	6.9	6.3	9.3	7.2	9.4		10.7	7.8	7.3	0.042
16.7	16.6	21.7	9.8	13.0	13.7		10.6	14.8	11.8	0.063
20.9	17.4	19.9	11.3	12.9	11.7		8.2	7.6	6.7	0.125
11.4	18.5	19.7	15.8	16.5	12.4		13.4	11.6	11.5	0.250
18.6	15.2	11.7	8.0	5.6	4.5		13.6	13.8	9.2	1.000
14.3	19.9	10.8	14.5	14.6	13.9		9.2	14.7	10.4	2.000
14.1	12.4	8.8	10.0	12.9	10.3		7.1	8.1	15.4	6.000
10.3	6.4	11.0	7.5	10.4	8.1		10.2	15.3	19.2	9.000
9.3	11.3	8.1	10.8	6.9	10.9		4.5	7.0	11.9	13.000
9.3	13.9	7.5	8.4	3.4	6.6		4.3	11.1	7.4	16.000
8.8	7.2	11.0	5.1	11.3	8.1		11.5	3.9	4.4	20.000
10.8	10.4	7.1	5.3	14.4	5.7		2.8	5.6	9.4	23.000
7.6	7.2	11.3	10.9	14.2	5.3		3.9	9.9	7.9	27.000
11.4	9.9	8.0	2.8	8.9	8.2		6.6	8.4	8.8	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E115

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
45	60	77	77	71	77		69	40	38	0.000
39	44	80	75	61	80		40	64	64	0.021
36	54	74	57	68	76		55	64	44	0.042
31	63	42	67	68	72		59	48	60	0.063
42	54	46	70	69	65		61	69	51	0.125
37	38	41	51	55	65		66	61	55	0.250
35	56	78	80	84	71		34	53	54	1.000
53	27	61	41	52	54		36	28	64	2.000
28	46	52	48	72	68		53	45	43	6.000
15	41	56	66	65	43		47	58	46	9.000
18	58	45	65	57	56		39	49	33	13.000
19	38	45	52	47	51		46	51	47	16.000
21	35	35	51	63	42		61	38	36	20.000
13	47	47	35	21	46		46	36	31	23.000
23	25	42	40	48	42		35	14	46	27.000
11	30	35	51	29	37		29	26	48	30.000
17	34	39	44	41	42		43	29	40	PTS (dB)
53	63	80	80	84	80		69	69	64	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F1

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
68	70	70	59	61	58		68	56	54	0.000
53	60	71	59	71	58		58	66	54	0.021
38	50	71	69	68	68		68	56	54	0.042
38	50	80	78	80	58		58	56	54	0.063
28	60	80	68	80	68		58	66	54	0.125
59	61	71	79	71	69		59	57	45	0.250
39	51	61	69	71	69		59	57	45	1.000
38	50	60	58	50	48		48	56	34	2.000
28	50	50	48	50	48		48	36	24	6.000
44	46	56	54	46	54		44	42	20	9.000
24	36	46	44	46	44		44	32	30	13.000
13	25	35	53	45	43		43	31	29	16.000
12	24	34	42	44	42		42	40	28	20.000
11	23	33	51	53	41		41	29	27	23.000
10	30	32	50	42	50		40	38	26	27.000
9	21	31	49	41	29		39	37	25	30.000
11	25	33	48	45	41		41	36	27	PTS (dB)
68	70	80	79	80	69		68	66	54	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E138

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
68	74	74	77	82	64		60	70	46	0.000
51	67	53	71	81	63		58	59	45	0.021
56	69	62	80	80	62		67	68	45	0.042
71	63	93	81	81	73		68	59	35	0.063
84	68	95	88	88	80		68	62	52	0.125
58	74	94	82	82	84		59	70	36	0.250
84	84	94	82	82	74		70	91	69	1.000
68	74	84	82	82	64		60	60	46	2.000
48	44	64	72	62	54		40	50	26	6.000
38	54	34	52	42	44		30	20	16	9.000
38	54	54	52	52	44		30	40	46	13.000
38	44	54	52	52	54		40	60	46	16.000
38	34	64	52	62	44		30	30	36	20.000
28	54	54	42	52	34		40	40	46	23.000
28	44	34	32	22	44		40	30	46	27.000
38	44	44	52	42	44		30	40	36	30.000
33	44	49	44	44	41		35	35	41	PTS (dB)
84	84	95	88	88	84		70	91	69	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G2

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
59	86	73	81	88	108		69	81	64	0.000
64	74	78	76	68	80		74	80	64	0.021
53	63	77	75	87	89		88	79	63	0.042
52	82	76	84	86	88		82	78	62	0.063
71	81	95	93	85	87		81	77	51	0.125
70	90	94	92	64	86		80	76	60	0.250
39	59	73	91	73	65		59	65	49	1.000
28	48	62	70	62	64		48	54	48	2.000
27	37	61	49	51	63		47	53	37	6.000
26	46	50	48	50	62		36	42	36	9.000
32	39	35	44	40	45		36	42	33	13.000
31	38	34	32	48	39		38	39	32	16.000
28	43	45	41	35	41		42	39	39	20.000
37	42	50	42	40	47		41	35	38	23.000
22	39	31	41	43	49		36	35	36	27.000
19	38	32	48	41	48		45	42	32	30.000
27	41	40	43	40	46		41	38	36	PTS (dB)
71	90	95	93	88	108		88	81	64	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G20

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
35	79	83	81	85	84		70	59	52	0.000
81	52	78	76	68	71		69	69	37	0.021
46	63	62	80	78	79		66	61	57	0.042
49	52	83	88	76	67		68	60	50	0.063
56	45	78	83	75	93		69	79	56	0.125
56	50	82	90	90	87		57	55	51	0.250
48	48	79	74	76	69		69	65	50	1.000
43	51	78	73	84	83		59	68	56	2.000
40	54	69	64	36	45		41	40	64	6.000
23	45	52	51	63	51		46	31	43	9.000
23	28	33	60	44	46		37	38	14	13.000
18	33	46	52	48	38		43	37	35	16.000
23	36	48	45	43	26		48	41	40	20.000
34	37	48	39	56	41		37	45	36	23.000
27	40	13	60	64	56		38	32	43	27.000
16	27	20	51	52	35		35	39	32	30.000
25	35	32	49	53	39		40	39	38	PTS (dB)
81	79	83	90	90	93		70	79	64	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G5

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
70	97	85	82	92	94		77	71	69	0.000
55	59	71	66	85	71		58	67	54	0.021
43	59	68	81	77	76		67	65	54	0.042
72	92	106	96	106	95		82	88	69	0.063
72	92	99	94	106	91		63	81	69	0.125
66	71	74	93	99	99		90	85	69	0.250
62	80	89	86	71	78		67	76	64	1.000
57	82	79	73	74	81		56	69	55	2.000
62	73	71	51	63	68		59	58	52	6.000
31	58	67	64	64	61		60	60	69	9.000
42	48	49	36	55	71		38	51	47	13.000
29	66	46	54	54	48		34	36	38	16.000
31	44	40	52	52	50		31	37	34	20.000
28	41	44	40	61	49		40	42	53	23.000
32	33	45	32	54	54		30	44	35	27.000
31	46	38	44	54	50		43	53	46	30.000
31	41	42	42	56	51		36	44	42	PTS (dB)
72	97	106	96	106	99		90	88	69	MAXIMUM TS (dB)

Group 2 - Postexposure Threshold Shifts

Animals:	E17R*
	F12R
	F24R
	F120R
	H32R
	G16R

*R refers to the right ear

GROUP 2

GROUP MEAN POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: Low peak 139 dB; 100 Impulses; 0.097 J/M^2/impulse

FREQUENCY (kHz)										
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (DAYS)
58	63	72	67	76	74		59	59	42	0.000
51	64	67	66	70	70		53	58	41	0.021
50	69	69	74	71	71		58	61	43	0.042
54	70	75	68	73	73		61	62	44	0.063
51	60	67	66	74	73		63	65	47	0.125
51	67	75	77	84	80		66	60	47	0.250
67	68	75	72	76	78		63	55	53	1.000
61	70	72	66	70	71		61	51	44	2.000
43	55	49	55	61	61		49	41	36	6.000
38	49	51	55	56	59		46	48	38	9.000
32	43	46	43	44	53		42	38	32	13.000
31	41	45	44	47	51		45	41	29	16.000
27	36	40	37	39	50		36	35	26	20.000
24	37	41	38	40	39		38	37	25	23.000
22	33	37	43	45	43		32	34	29	27.000
20	31	38	38	45	40		28	35	27	30.000
23	34	39	39	42	43		34	35	27	MEAN GROUP PTS (dB)
11.1	8.8	9.5	10.2	12.5	11.2		10.3	9.2	12.0	SD GROUP PTS (dB)
68	77	85	80	86	87		73	70	59	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)										
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
14.1	11.7	12.3	14.6	13.9	13.4		11.5	5.3	7.4	0.000
10.1	15.2	7.5	6.3	5.0	12.2		12.4	13.2	13.3	0.021
13.8	11.2	12.6	6.3	14.1	9.4		8.3	3.7	15.3	0.042
17.0	10.5	9.0	7.3	8.2	7.3		8.0	8.7	12.6	0.063
8.6	9.8	12.2	19.6	10.8	11.1		8.7	11.7	10.1	0.125
14.5	14.0	14.6	10.7	11.7	17.8		10.8	11.4	14.1	0.250
11.3	11.0	14.1	12.6	9.0	17.3		10.0	7.2	10.5	1.000
9.1	11.6	10.1	8.4	12.4	13.3		11.4	15.5	14.2	2.000
16.4	13.4	20.7	16.8	12.8	9.2		9.7	8.6	12.5	6.000
8.6	7.9	13.3	14.1	11.4	11.5		16.3	7.1	9.8	9.000
8.4	8.8	6.4	14.3	14.4	5.4		5.9	14.6	11.5	13.000
15.8	16.6	8.6	8.9	5.8	13.7		2.4	14.0	11.3	16.000
13.8	10.0	8.0	16.7	19.5	12.5		4.9	18.4	18.1	20.000
13.4	9.6	8.7	16.9	19.3	22.1		12.1	13.0	14.4	23.000
10.4	10.4	13.0	8.1	9.6	10.1		15.7	15.7	10.5	27.000
12.2	11.8	15.0	10.7	6.8	10.4		14.0	7.8	8.1	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E17

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
36	45	58	45	62	52		45	54	35	0.000
37	40	55	58	67	52		42	35	24	0.021
47	60	45	68	47	57		52	55	14	0.042
25	56	69	56	63	63		56	45	26	0.063
34	41	46	28	57	57		47	45	42	0.125
28	48	50	58	69	51		47	40	25	0.250
66	56	49	53	73	66		73	62	69	1.000
55	56	76	65	67	55		46	26	20	2.000
26	52	8	65	75	52		36	31	49	6.000
23	37	62	48	45	60		36	37	48	9.000
36	33	50	55	51	61		36	54	36	13.000
43	51	49	49	52	54		47	53	33	16.000
20	37	29	43	46	53		29	50	12	20.000
3	26	32	27	32	24		30	11	30	23.000
10	20	23	39	43	31		22	20	27	27.000
3	21	20	48	47	36		8	21	30	30.000
9	26	26	39	42	36		23	26	25	PTS (dB)
66	60	76	68	75	66		73	62	69	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F12

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
78	68	68	63	88	66		49	54	35	0.000
68	58	68	73	68	66		39	54	50	0.021
68	78	78	72	68	66		49	64	50	0.042
78	78	88	72	78	76		59	64	50	0.063
49	69	69	83	79	77		60	75	31	0.125
69	69	69	83	99	77		70	65	62	0.250
78	79	79	73	79	77		60	45	51	1.000
78	79	79	63	79	77		60	55	41	2.000
68	79	59	53	59	57		50	55	41	6.000
44	54	64	58	54	52		55	50	36	9.000
44	54	54	48	54	52		45	50	36	13.000
33	53	53	47	53	51		44	49	25	16.000
42	52	52	56	42	50		33	48	24	20.000
41	51	51	45	41	49		42	37	23	23.000
40	40	50	44	50	48		41	46	32	27.000
29	39	49	33	39	57		40	45	31	30.000
38	46	51	45	43	51		39	44	28	PTS (dB)
78	79	88	83	99	77		70	75	62	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F24

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
65	63	84	90	94	90		71	64	47	0.000
55	63	74	70	74	80		61	64	47	0.021
45	53	74	80	74	70		61	64	47	0.042
55	63	64	70	64	70		51	64	37	0.063
55	63	74	70	64	70		61	64	47	0.125
65	73	94	90	94	100		61	74	37	0.250
65	63	74	80	84	80		51	64	47	1.000
55	63	74	70	74	80		61	54	47	2.000
55	43	54	70	64	60		41	44	27	6.000
45	43	54	60	54	50		51	44	37	9.000
25	43	44	20	54	50		41	14	27	13.000
55	53	54	50	44	60		41	54	27	16.000
45	33	44	50	54	50		41	44	47	20.000
25	33	34	50	54	50		31	44	37	23.000
25	43	54	50	54	60		41	54	37	27.000
37	47	50	38	44	44		29	36	33	30.000
33	39	45	47	51	51		35	45	38	PTS (dB)
65	73	94	90	94	100		71	74	47	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F120

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
62	68	62	70	72	76		62	62	54	0.000
51	77	61	69	71	65		51	71	53	0.021
60	76	70	68	80	74		60	60	52	0.042
60	85	69	67	79	73		69	69	51	0.063
58	64	58	76	78	82		68	78	60	0.125
47	73	77	75	77	71		77	57	59	0.250
66	82	76	74	66	70		76	56	58	1.000
65	81	55	63	65	69		75	65	62	2.000
44	60	54	62	44	68		64	44	46	6.000
33	59	43	51	53	57		53	53	45	9.000
34	46	39	48	52	48		39	34	36	13.000
19	36	36	51	50	48		45	34	36	16.000
22	38	42	40	42	46		42	32	34	20.000
21	43	37	33	33	43		43	39	37	23.000
17	42	34	40	38	37		40	34	35	27.000
22	38	32	40	42	36		42	32	34	30.000
21	40	36	38	39	41		42	34	35	PTS (dB)
66	85	77	76	80	82		77	78	62	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H32

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
54	57	69	64	80	81		73	53	41	0.000
47	84	70	68	77	86		73	69	50	0.021
49	65	79	83	89	85		72	65	39	0.042
53	66	79	77	83	85		72	67	38	0.063
54	60	75	73	84	87		68	60	51	0.125
49	53	79	78	88	91		66	65	46	0.250
79	58	91	88	89	111		55	54	38	1.000
57	81	82	79	87	89		73	66	53	2.000
29	52	65	58	76	76		52	34	39	6.000
45	52	54	77	78	82		64	46	41	9.000
21	49	51	56	32	60		52	43	44	13.000
18	41	44	37	40	66		47	36	43	16.000
24	31	34	21	49	71		39	35	39	20.000
36	42	52	59	67	65		58	47	25	23.000
23	25	39	54	54	44		42	39	36	27.000
17	21	53	50	58	39		35	36	25	30.000
25	29	45	46	57	55		44	39	31	PTS (dB)
79	84	91	88	89	111		73	69	53	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G16

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
52	79	89	72	59	78		53	64	38	0.000
49	64	73	59	63	73		54	57	25	0.021
28	81	70	72	68	74		53	60	56	0.042
50	70	79	65	72	72		59	65	61	0.063
55	61	77	65	82	66		71	65	54	0.125
49	85	80	76	75	90		74	61	52	0.250
48	71	80	62	68	64		63	50	56	1.000
56	59	65	54	51	58		51	39	40	2.000
33	44	55	23	51	54		51	37	16	6.000
40	51	28	35	50	56		18	57	20	9.000
29	32	39	32	20	50		37	32	11	13.000
17	10	33	29	41	26		44	18	10	16.000
9	22	38	13	0	32		34	0	-2	20.000
18	29	40	13	11	3		24	42	-2	23.000
15	25	23	32	30	41		3	12	9	27.000
11	21	21	21	41	26		13	37	12	30.000
13	24	31	20	21	26		19	23	4	PTS (dB)
56	85	89	76	82	90		74	65	61	MAXIMUM TS (dB)

Group 3 - Postexposure Threshold Shifts

Animals: E109R*
G30R
E144R
H16R
H1R
H42R

*R refers to the right ear

GROUP 3

GROUP MEAN POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: High Peak 139 dB; 100 Impulses; 0.015 J/M^2/impulse

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
47	57	58	53	58	67		43	37	29	0.000
42	60	66	58	63	64		54	58	44	0.021
55	61	75	75	68	73		63	60	46	0.042
48	65	73	73	70	75		61	65	50	0.063
49	68	75	68	68	77		65	64	46	0.125
43	57	65	66	64	73		55	56	50	0.250
37	44	57	48	56	57		51	46	31	1.000
26	52	54	45	39	48		39	32	24	2.000
23	36	41	39	49	41		24	31	20	6.000
27	28	35	41	38	39		34	24	22	9.000
12	27	34	33	27	34		21	24	12	13.000
12	27	29	31	29	40		18	24	21	16.000
17	28	26	27	24	35		16	14	14	20.000
13	27	31	21	24	27		17	17	11	23.000
10	26	24	26	29	29		17	21	13	27.000
13	22	27	25	27	25		13	19	16	30.000
13	26	27	25	26	29		16	18	14	MEAN GROUP PTS(dB)
6.0	9.1	8.6	7.0	11.1	13.9		5.2	10.2	13.1	SD GROUP PTS (dB)
62	75	85	80	76	83		69	72	57	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
9.5	16.1	11.3	21.3	13.7	11.1		10.1	13.9	5.4	0.000
13.3	16.5	16.7	10.2	8.3	14.3		22.4	19.9	19.8	0.021
9.0	20.4	17.6	15.7	7.3	18.1		15.4	22.1	19.9	0.042
17.6	21.3	16.1	19.7	13.7	17.9		13.0	19.7	15.9	0.063
14.3	21.3	12.6	17.2	10.3	13.2		12.9	14.5	16.9	0.125
4.8	11.2	10.1	11.6	8.1	3.5		10.1	11.9	13.6	0.250
11.7	7.8	10.3	14.7	14.3	5.8		8.3	15.4	10.5	1.000
16.6	8.6	7.8	10.8	11.7	14.8		20.2	15.3	16.4	2.000
12.5	11.1	8.6	12.6	9.8	13.5		15.6	18.7	15.0	6.000
10.4	9.4	8.3	9.8	10.8	14.4		15.9	9.0	13.4	9.000
10.5	13.0	13.0	16.3	11.2	18.2		12.9	12.8	12.4	13.000
5.9	14.5	9.7	12.7	8.9	19.6		10.5	13.0	16.2	16.000
8.4	15.1	14.7	12.8	14.4	23.9		9.6	12.0	18.4	20.000
9.9	11.5	11.2	10.4	10.8	13.7		5.3	9.4	13.0	23.000
8.1	7.7	20.5	7.2	18.0	15.6		6.3	13.7	12.9	27.000
10.0	7.7	9.9	5.7	9.9	13.4		6.4	15.8	14.7	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E109

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
40	31	50	53	55	49		31	32	20	0.000
30	31	40	43	55	39		31	22	10	0.021
40	31	40	53	55	49		41	22	10	0.042
40	32	50	53	55	49		41	31	20	0.063
45	31	63	61	64	64		44	52	17	0.125
43	56	60	63	65	69		51	42	40	0.250
60	52	50	53	45	49		41	23	18	1.000
40	42	40	33	35	29		11	11	0	2.000
40	42	50	43	55	49		11	23	8	6.000
35	36	26	47	42	30		29	25	34	9.000
28	19	19	10	15	3		22	8	7	13.000
18	5	15	24	17	21		24	26	11	16.000
12	19	9	28	21	15		2	8	7	20.000
12	10	19	8	21	5		9	11	6	23.000
12	20	9	18	11	5		9	11	6	27.000
16	13	13	21	14	9		12	14	9	30.000
13	16	13	19	17	9		8	11	7	PTS (dB)
60	56	63	63	65	69		51	52	40	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G30

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
62	73	56	65	51	64		37	27	28	0.000
48	64	56	71	57	81		72	71	57	0.021
56	57	74	79	70	68		68	58	50	0.042
55	70	68	86	64	72		60	76	64	0.063
46	58	66	86	76	62		76	46	67	0.125
48	55	79	76	69	78		73	62	68	0.250
36	47	41	65	72	62		57	52	30	1.000
29	52	59	57	48	66		40	31	15	2.000
36	35	41	62	61	47		39	47	32	6.000
32	25	49	56	52	60		62	22	30	9.000
19	50	45	54	45	51		40	41	27	13.000
15	43	35	56	39	68		26	43	51	16.000
6	37	49	49	48	61		21	6	41	20.000
16	40	31	35	38	27		23	13	5	23.000
9	27	-4	37	37	44		24	34	18	27.000
17	16	40	26	41	29		19	33	37	30.000
12	30	29	37	41	40		22	22	25	PTS (dB)
62	73	79	86	76	81		76	76	68	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA E144

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
41	71	41	11	36	75		61	59	31	0.000
60	61	90	50	55	74		80	79	60	0.021
59	79	89	102	74	103		79	87	67	0.042
58	83	78	100	75	101		68	84	58	0.063
51	88	71	71	76	95		71	87	51	0.125
41	51	71	61	66	75		51	59	51	0.250
30	30	60	30	35	54		60	68	35	1.000
19	49	49	49	34	63		59	57	39	2.000
18	38	28	28	33	52		38	56	38	6.000
7	17	27	37	32	51		17	35	37	9.000
6	16	16	26	21	40		16	34	16	13.000
15	25	25	25	20	39		15	33	15	16.000
14	34	24	24	19	48		14	32	26	20.000
23	33	33	23	18	47		13	31	33	23.000
12	32	42	32	57	46		22	40	32	27.000
21	31	31	31	36	45		21	39	31	30.000
17	32	33	27	33	47		17	36	30	PTS (dB)
60	88	90	102	76	103		80	87	67	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H16

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
50	65	72	58	69	80		45	35	37	0.000
23	67	68	59	67	61		24	53	34	0.021
67	43	78	72	64	65		46	53	38	0.042
18	47	64	48	56	64		51	62	47	0.063
26	68	98	40	56	85		62	71	41	0.125
47	41	66	48	55	73		44	40	30	0.250
31	42	70	33	63	54		45	44	47	1.000
-4	43	61	52	20	41		17	28	13	2.000
14	15	39	33	53	16		28	27	2	6.000
29	18	32	43	20	23		29	23	7	9.000
7	17	44	48	26	25		1	12	-3	13.000
4	25	36	23	29	59		25	11	22	16.000
29	1	19	15	15	57		9	4	-7	20.000
-5	16	25	10	14	21		18	27	8	23.000
-4	13	20	21	16	18		10	10	6	27.000
-5	20	18	34	24	29		9	-5	0	30.000
4	13	21	20	17	31		11	9	2	PTS (dB)
67	68	98	72	69	85		62	71	47	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H1

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
38	51	66	66	73	72		46	47	31	0.000
47	80	72	61	72	65		63	60	61	0.021
57	74	84	73	69	74		68	65	58	0.042
69	86	83	77	87	78		69	59	60	0.063
70	87	70	64	57	70		58	62	44	0.125
35	63	66	71	55	75		58	66	53	0.250
28	41	56	46	53	56		44	38	36	1.000
39	58	58	47	48	53		48	28	36	2.000
19	48	35	39	42	37		29	28	31	6.000
27	36	38	32	42	41		41	29	20	9.000
-2	31	35	36	35	51		25	21	25	13.000
15	43	22	26	37	33		22	24	20	16.000
19	40	38	32	34	23		25	26	22	20.000
12	32	24	27	37	30		22	12	20	23.000
12	31	24	26	37	31		20	21	21	27.000
7	31	32	21	27	26		13	15	16	30.000
13	34	30	27	34	27		20	19	20	PTS (dB)
70	87	84	77	87	78		69	66	61	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H42

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
53	49	64	64	67	62		40	21	30	0.000
43	54	67	64	73	63		54	60	45	0.021
53	80	81	72	75	82		74	72	53	0.042
46	73	96	73	83	86		77	80	53	0.063
53	73	78	85	79	84		79	67	56	0.125
45	74	49	79	76	70		53	65	59	0.250
38	48	64	62	70	65		58	53	21	1.000
34	64	55	30	51	38		57	39	39	2.000
8	35	50	30	48	48		0	3	12	6.000
33	37	35	30	39	29		26	8	7	9.000
13	28	44	25	18	36		21	26	2	13.000
4	22	41	32	35	21		-1	9	5	16.000
23	37	17	15	8	4		27	8	-2	20.000
21	32	51	22	15	31		19	8	-4	23.000
21	32	51	22	15	31		19	8	-4	27.000
21	18	25	20	21	11		4	15	6	30.000
22	30	36	20	14	19		17	10	-1	PTS (dB)
53	80	96	85	83	86		79	80	59	MAXIMUM TS (dB)

Group 4 - Postexposure Threshold Shifts

Animals: D22R*
F113R
F2R
H12R
H2R
G9R

*R refers to the right ear

GROUP 4

GROUP MEAN POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: Low Peak 131 dB; 100 Impulses; 0.015 J/M^2/impulse

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
35	40	47	51	60	48		39	43	25	0.000
41	49	45	51	51	60		45	45	32	0.021
40	56	45	54	64	61		50	41	37	0.042
38	50	55	60	61	60		50	45	36	0.063
39	54	59	63	68	68		52	49	39	0.125
36	57	64	64	64	63		44	47	42	0.250
36	38	44	52	59	49		34	31	20	1.000
31	39	41	42	42	38		19	24	20	2.000
24	36	32	36	41	32		22	18	15	6.000
18	30	30	30	36	27		17	21	11	9.000
15	19	22	32	25	25		19	17	14	13.000
8	21	27	32	27	15		17	9	17	16.000
9	19	22	21	19	15		20	10	12	20.000
13	20	19	17	19	17		16	10	13	23.000
10	20	25	23	18	12		16	9	12	27.000
8	18	18	22	19	12		18	16	10	30.000
10	19	21	21	19	14		18	12	12	MEAN GROUP PTS (dB)
9.5	9.0	10.7	7.3	12.0	12.5		13.3	1.4	5.6	SD GROUP PTS (dB)
50	66	69	68	75	72		64	57	46	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
16.9	20.3	18.3	13.1	21.9	24.6		20.6	13.4	15.6	0.000
15.9	22.7	19.4	16.5	21.0	24.5		20.2	16.0	12.0	0.021
19.2	20.6	23.7	14.2	25.3	26.6		24.6	24.6	18.5	0.042
22.3	29.1	23.2	23.2	32.5	30.5		29.2	25.4	21.1	0.063
21.3	19.3	26.5	20.6	15.4	19.0		21.8	20.1	16.0	0.125
12.7	8.5	14.8	19.0	13.2	31.3		16.5	11.6	12.0	0.250
12.6	17.1	19.3	17.2	15.2	21.5		26.6	19.5	14.3	1.000
12.9	12.4	10.8	9.2	14.2	11.4		14.9	16.4	11.4	2.000
12.7	19.5	15.8	11.9	21.4	21.0		8.0	11.0	9.4	6.000
16.7	15.8	14.2	16.1	11.7	14.0		9.1	14.8	10.4	9.000
15.5	11.8	18.8	15.4	10.3	21.0		11.0	7.1	7.4	13.000
12.1	15.9	14.1	22.0	14.6	16.7		9.0	3.0	8.2	16.000
7.0	11.5	11.3	11.7	14.3	11.1		20.3	6.5	5.3	20.000
11.7	7.7	10.8	5.2	11.1	16.0		16.9	3.6	7.7	23.000
14.8	7.8	9.4	6.3	13.4	15.6		10.1	5.0	9.7	27.000
8.6	10.6	15.7	9.2	13.9	11.1		12.0	6.3	7.4	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA D22

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
47	49	53	54	54	41		28	23	21	0.000
57	59	53	44	44	51		38	33	11	0.021
57	49	53	54	54	51		48	23	21	0.042
37	60	53	54	54	51		28	22	29	0.063
57	60	73	74	64	71		47	32	21	0.125
57	60	63	64	54	61		38	32	31	0.250
54	60	61	54	54	57		12	10	8	1.000
47	50	53	54	44	41		17	12	11	2.000
43	41	43	44	44	41		19	15	0	6.000
31	42	38	47	40	41		24	24	13	9.000
45	37	52	51	24	65		29	19	18	13.000
25	33	38	35	36	33		21	7	12	16.000
19	17	32	19	20	7		9	9	8	20.000
29	18	22	19	10	7		6	12	7	23.000
29	18	32	19	0	7		6	2	-3	27.000
23	21	46	22	23	11		9	15	10	30.000
25	19	33	20	13	8		8	10	6	PTS (dB)
57	60	73	74	64	71		48	33	31	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F113

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
32	51	55	44	60	42		38	47	45	0.000
31	59	55	46	54	53		49	49	42	0.021
30	56	37	51	60	65		51	37	41	0.042
33	59	40	58	64	64		49	48	35	0.063
57	71	90	54	71	64		44	52	40	0.125
39	68	71	66	68	65		46	56	39	0.250
26	51	36	66	64	69		59	45	31	1.000
33	52	54	35	20	47		45	50	39	2.000
27	45	46	37	47	40		33	31	19	6.000
29	38	46	44	43	23		29	33	29	9.000
12	21	32	47	30	24		26	27	19	13.000
1	16	29	38	18	3		24	5	15	16.000
7	24	30	35	13	17		54	18	10	20.000
9	22	32	19	11	16		48	10	9	23.000
-7	21	34	18	10	3		19	14	19	27.000
9	17	19	28	8	11		32	13	2	30.000
5	21	29	25	11	12		39	14	10	PTS (dB)
57	71	90	66	71	69		59	56	45	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA F2

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
50	59	52	51	69	68		51	57	22	0.000
59	68	61	60	68	97		60	66	41	0.021
68	77	70	59	97	96		69	75	68	0.042
74	76	89	88	106	105		96	80	68	0.063
50	70	72	81	89	98		81	67	62	0.125
39	48	81	90	78	97		60	36	61	0.250
40	39	52	61	69	58		61	37	32	1.000
29	38	41	50	48	47		20	16	21	2.000
28	37	40	49	67	56		19	15	20	6.000
27	36	39	28	36	35		18	14	9	9.000
6	25	18	27	35	24		17	13	18	13.000
5	24	27	26	34	23		26	12	17	16.000
14	33	26	15	33	22		25	11	16	20.000
13	32	25	14	32	46		14	10	25	23.000
12	31	34	23	31	40		33	9	24	27.000
11	30	23	22	30	29		32	18	23	30.000
13	31	27	19	32	34		26	12	22	PTS (dB)
74	77	89	90	106	105		96	80	68	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H12

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
43	43	58	53	88	70		65	52	32	0.000
45	62	44	59	64	66		48	43	36	0.021
26	67	52	59	73	69		58	34	35	0.042
32	50	69	68	73	65		45	53	24	0.063
22	42	58	65	62	68		48	65	40	0.125
28	61	70	60	69	77		16	45	28	0.250
37	12	64	61	80	61		27	37	1	1.000
40	46	35	45	57	39		18	30	27	2.000
24	60	35	39	53	45		22	25	19	6.000
26	41	30	21	45	38		18	42	9	9.000
5	18	24	24	29	17		25	10	15	13.000
22	41	45	64	37	32		6	6	33	16.000
3	15	23	18	23	25		20	-2	20	20.000
1	19	20	17	30	20		11	12	18	23.000
-1	23	22	24	21	12		16	7	4	27.000
2	21	8	27	31	8		6	28	4	30.000
1	20	18	22	26	16		13	12	12	PTS (dB)
45	67	70	68	88	77		65	65	40	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H2

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
36	35	55	71	66	61		48	49	32	0.000
33	37	49	71	63	72		64	57	38	0.021
38	68	57	73	79	68		72	64	43	0.042
46	61	54	74	64	67		67	58	53	0.063
42	61	50	78	80	71		71	62	49	0.125
33	46	58	72	73	73		61	62	50	0.250
40	36	38	51	50	42		48	53	35	1.000
10	27	31	38	54	36		12	30	15	2.000
15	31	20	32	34	5		27	23	25	6.000
-4	21	21	35	38	19		10	7	6	9.000
17	8	8	31	29	14		17	22	16	13.000
-4	15	15	31	36	1		18	9	12	16.000
1	27	17	35	33	23		21	11	10	20.000
0	18	12	25	25	15		15	14	16	23.000
0	18	16	34	34	17		17	8	15	27.000
1	18	7	30	28	17		20	12	12	30.000
1	20	13	31	30	18		19	11	13	PTS (dB)
46	68	58	78	80	73		72	64	53	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA G9

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
4	2	10	31	22	4		6	30	-2	0.000
19	8	7	24	12	23		8	22	24	0.021
19	19	2	30	23	15		4	10	15	0.042
6	-7	22	20	6	10		13	10	8	0.063
5	21	13	26	45	38		19	18	20	0.125
20	57	38	32	43	4		44	49	42	0.250
18	27	12	19	37	9		-4	5	11	1.000
25	23	29	30	31	16		0	5	8	2.000
6	2	5	15	4	7		10	0	6	6.000
-3	2	7	4	13	4		4	6	-3	9.000
5	5	-2	10	6	5		-1	10	-1	13.000
1	-4	7	-4	1	-5		5	13	14	16.000
7	0	1	6	-5	-4		-7	13	6	20.000
23	8	1	10	7	-2		0	4	4	23.000
25	7	13	17	10	-6		5	16	14	27.000
2	-2	3	5	-3	-5		8	12	7	30.000
14	3	5	9	2	-4		2	11	8	PTS (dB)
25	57	38	32	45	38		44	49	42	MAXIMUM TS (dB)

Group 5 - Postexposure Threshold Shifts

Animals: [redacted]*
K116R
K103R
[redacted]
K108R
K21R

*R refers to the right ear

GROUP 5

GROUP MEAN POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: High peak 135 dB; 100 Impulses; 0.006 J/M^2/impulse

FREQUENCY (kHz)										
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
15	23	26	34	44	33	30	26	23	19	0.000
18	20	24	32	34	35	28	31	28	28	0.021
18	20	31	33	33	35	30	29	23	33	0.042
14	20	28	25	31	38	25	31	32	21	0.063
16	27	24	25	28	31	26	21	26	21	0.125
17	28	23	27	24	27	26	22	25	19	0.250
17	24	25	26	24	30	29	22	15	19	1.000
11	12	21	19	17	19	12	20	8	12	2.000
7	8	22	18	15	16	15	17	11	6	6.000
4	6	8	16	9	13	14	10	10	7	9.000
5	12	13	7	9	12	9	10	7	9	13.000
5	5	12	3	8	7	8	7	4	4	16.000
3	8	11	9	12	7	7	3	3	4	20.000
4	4	10	6	7	10	10	8	9	2	23.000
0	4	8	9	5	7	12	5	3	7	27.000
1	1	10	10	8	8	3	7	4	8	30.000
2	4	10	8	8	8	8	6	5	5	MEAN GROUP PTS (dB)
5.0	4.6	10.1	9.5	9.8	10.5	10.5	6.1	5.5	4.1	SD GROUP PTS (dB)
29	39	41	43	50	47	45	44	42	39	AVG. MAXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)										
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
10.7	13.6	18.4	14.1	13.4	19.6	16.9	14.8	17.3	12.3	0.000
9.4	13.2	11.5	15.7	18.4	18.4	14.9	13.3	17.4	8.1	0.021
18.1	19.4	21.4	20.1	20.4	17.3	15.6	13.0	15.9	13.4	0.042
9.3	15.5	23.5	20.9	18.3	18.1	17.3	17.8	18.6	17.8	0.063
22.0	26.5	22.5	19.2	24.0	19.8	24.3	16.7	14.7	12.7	0.125
15.9	26.3	27.3	23.1	20.8	25.7	23.1	20.9	24.5	20.9	0.250
11.3	20.3	19.1	23.9	20.6	30.4	26.2	22.8	15.9	17.6	1.000
9.1	13.7	20.5	17.4	9.7	21.4	11.3	19.0	11.4	10.1	2.000
4.5	4.3	14.7	19.2	15.5	13.9	11.3	16.9	14.4	7.5	6.000
7.9	10.1	13.2	18.0	12.4	13.7	18.2	14.3	14.3	12.9	9.000
8.0	15.4	20.0	15.3	11.0	14.7	19.5	11.2	8.4	21.6	13.000
3.0	6.9	13.8	7.1	11.7	11.3	9.0	8.8	8.1	7.8	16.000
7.8	14.8	17.0	11.9	17.7	16.2	13.6	5.3	1.6	11.8	20.000
7.7	9.2	8.6	11.8	9.3	14.9	13.6	9.5	14.8	4.4	23.000
3.2	4.3	7.4	13.5	9.6	9.1	17.3	7.2	3.1	7.9	27.000
4.9	6.2	11.8	9.9	6.7	8.7	6.2	8.5	7.7	6.5	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K68

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
0	4	8	24	52	42	41	48	18	24	0.000
18	22	26	42	50	50	39	46	46	32	0.021
6	10	14	50	58	38	37	24	24	30	0.042
4	28	22	18	46	46	35	22	32	18	0.063
12	36	30	26	44	44	23	20	30	16	0.125
9	23	17	23	31	21	30	27	17	13	0.250
17	31	25	31	29	39	38	35	25	31	1.000
15	9	23	29	27	17	16	43	23	19	2.000
3	7	11	17	25	25	14	11	11	-3	6.000
1	-5	-1	15	13	13	12	-1	-1	-5	9.000
-1	3	7	13	1	11	0	7	-3	-7	13.000
5	-1	3	-1	-3	17	6	3	3	-1	16.000
3	-3	1	7	15	-5	4	1	1	-3	20.000
-2	2	6	2	0	0	-1	-4	-4	2	23.000
-4	0	4	0	-2	-2	7	-6	4	0	27.000
0	4	-2	4	2	2	1	-2	-2	4	30.000
-1	1	2	3	4	-1	3	-3	0	1	PTS (dB)
18	36	30	50	58	50	41	48	46	32	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K116

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
8	10	10	16	18	6	12	16	14	16	0.000
16	8	8	14	16	14	10	14	12	24	0.021
14	16	16	12	14	12	18	22	20	22	0.042
12	4	4	0	12	10	6	10	8	10	0.063
0	2	2	-2	0	8	-6	8	16	8	0.125
8	0	-10	6	-2	6	-8	6	4	-4	0.250
6	-2	-2	-6	6	-6	0	4	2	4	1.000
4	6	-4	-8	4	2	-2	-8	0	2	2.000
12	4	5	0	-8	0	-4	0	-2	9	6.000
0	2	2	-2	-10	-2	-6	-2	-4	8	9.000
8	0	-10	-14	-2	6	2	6	4	6	13.000
6	-2	-2	-6	6	-6	0	4	2	4	16.000
6	-2	-2	-6	-4	-6	-10	4	2	4	20.000
4	6	-4	-8	4	2	-2	2	0	2	23.000
2	4	4	0	2	0	-4	0	-2	0	27.000
0	-8	2	-2	0	-2	-6	8	-4	8	30.000
3	0	0	-4	1	-2	-6	4	-1	4	PTS (dB)
16	16	16	16	18	14	18	22	20	24	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K103

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
17	33	41	39	43	41	7	9	3	15	0.000
16	32	30	28	22	40	16	38	12	34	0.021
5	21	43	37	31	29	15	17	1	23	0.042
14	10	44	36	40	48	24	16	20	22	0.063
3	29	17	25	39	37	23	5	19	31	0.125
12	58	46	44	18	46	42	44	48	40	0.250
31	37	55	63	57	75	61	53	37	49	1.000
10	36	54	32	26	54	30	32	16	28	2.000
9	15	43	52	35	23	29	41	35	17	6.000
18	24	32	50	24	32	48	30	24	26	9.000
8	34	42	30	24	32	48	20	14	16	13.000
11	17	35	3	27	5	21	23	17	19	16.000
-11	35	43	31	45	33	29	11	5	27	20.000
-2	-6	22	0	24	12	28	20	4	-4	23.000
-3	3	11	29	23	21	17	9	3	5	27.000
-4	8	30	18	12	20	5	8	12	4	30.000
-5	10	26	19	26	22	20	12	6	8	PTS (dB)
31	58	55	63	57	75	61	53	48	49	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA H184

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
26	26	44	40	44	40	42	30	38	30	0.000
14	14	22	38	53	38	40	38	36	28	0.021
12	2	20	26	33	26	18	26	34	26	0.042
10	10	18	24	28	34	26	34	36	24	0.063
8	8	16	22	16	12	24	12	10	12	0.125
5	5	3	9	13	-1	11	-1	-3	9	0.250
3	3	13	7	1	-3	9	-3	-5	7	1.000
-1	-1	7	3	7	-7	5	3	-9	3	2.000
5	5	13	-1	3	-1	11	-1	-3	-1	6.000
0	0	8	4	8	1	6	4	2	4	9.000
4	4	2	-2	12	-2	0	-2	6	-2	13.000
4	4	12	-2	2	-2	10	-2	-4	-2	16.000
2	2	0	6	0	-4	-2	-4	4	-4	20.000
1	1	9	5	-1	-5	-3	5	3	5	23.000
-1	-1	7	3	-3	3	5	3	1	3	27.000
-3	-3	5	1	5	1	3	1	-1	1	30.000
-1	-1	5	3	0	-2	0	1	2	1	PTS (dB)
26	26	44	40	53	40	42	38	38	30	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K108

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
28	40	44	56	50	58	48	38	50	30	0.000
36	40	42	54	48	56	46	36	48	38	0.021
54	58	70	62	56	64	54	54	46	56	0.042
32	46	68	60	54	62	52	52	64	54	0.063
60	74	66	58	62	60	70	50	52	42	0.125
48	62	64	66	60	68	58	48	60	50	0.250
17	51	33	35	19	37	57	37	9	9	1.000
17	21	33	35	19	27	17	27	9	9	2.000
13	7	29	21	15	33	23	23	5	5	6.000
7	11	13	15	19	27	17	27	9	19	9.000
17	31	33	15	19	27	-3	27	19	49	13.000
4	8	20	12	16	24	14	4	-4	6	16.000
11	15	17	9	13	21	11	1	3	3	20.000
19	3	15	27	11	19	22	9	11	1	23.000
5	9	21	23	7	15	45	15	7	17	27.000
3	7	19	21	15	13	3	23	15	15	30.000
9	8	18	20	11	17	20	12	9	9	PTS (dB)
60	74	70	66	62	68	70	54	64	56	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K21

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
10	27	9	27	55	13	33	18	15	-3	0.000
8	7	17	15	13	11	19	15	13	15	0.021
16	15	25	13	9	39	39	33	11	43	0.042
14	23	13	11	9	27	7	51	31	1	0.063
12	11	11	19	7	25	25	29	27	19	0.125
20	19	19	17	25	25	23	7	25	7	0.250
28	27	27	25	33	38	11	5	23	15	1.000
24	3	13	21	19	24	7	21	9	11	2.000
3	12	32	20	18	16	16	30	18	10	6.000
-4	5	-5	13	1	9	9	3	31	-7	9.000
-6	3	3	1	-1	-3	7	1	-1	-9	13.000
3	2	2	10	-2	6	-4	10	8	0	16.000
10	-1	9	7	5	3	13	7	5	-3	20.000
2	21	11	9	7	35	15	19	37	9	23.000
0	9	-1	-3	5	3	3	7	5	17	27.000
10	-1	9	17	15	13	13	7	5	17	30.000
5	7	7	8	8	14	11	10	13	10	PTS (dB)
28	27	32	27	55	39	39	51	37	43	MAXIMUM TS (dB)

Group 6 - Postexposure Threshold Shifts

Animals:	K62R*
	K115R
	K69R
	K114R
	K102R
	K93R

*R refers to the right ear

GROUP 6

GROUP MEAN POSTEXPOSURE THRESHOLD SHIFTS (dB)

EXPOSURE: Low peak 127 dB; 100 Impulses; 0.006 J/M^2/impulse

FREQUENCY (kHz)										
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
2	4	10	7	11	11	17	7	10	8	0.000
10	12	8	9	6	16	12	7	10	12	0.021
5	9	8	4	14	20	17	13	15	18	0.042
8	6	11	7	9	20	20	15	16	13	0.063
6	4	11	14	10	15	15	14	10	19	0.125
8	7	6	9	7	10	15	13	15	13	0.250
10	11	15	8	8	18	6	8	9	2	1.000
3	7	11	14	4	9	14	5	15	8	2.000
3	9	10	6	11	9	12	3	15	12	6.000
4	3	2	7	6	6	5	4	7	10	9.000
3	3	1	3	7	7	3	7	6	4	13.000
1	0	6	3	3	3	5	4	3	4	16.000
-1	-2	1	3	2	2	2	13	3	4	20.000
1	0	1	2	3	3	0	2	3	2	23.000
4	-1	0	-1	4	6	1	5	4	1	27.000
3	2	1	2	4	7	2	0	1	0	30.000
2	0	1	2	3	4	1	5	3	2	MEAN GROUP PTS (dB)
4.4	2.6	4.7	6.5	2.4	5.1	1.5	6.1	2.2	1	SD GROUP PTS (dB)
18	25	23	23	20	35	36	29	32	31	AVG. MXIMUM TS (dB)

GROUP STANDARD DEVIATIONS (dB)

FREQUENCY (kHz)										
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
2.7	1.3	6.2	9.6	10.0	10.9	11.9	8.0	15.9	10.2	0.000
4.2	6.7	4.0	6.9	8.1	15.5	7.6	8.7	10.2	12.7	0.021
4.2	7.5	7.8	3.8	10.2	14.8	12.3	7.0	8.5	15.7	0.042
6.3	12.4	9.2	7.6	5.9	4.9	13.6	13.7	10.7	8.8	0.063
2.8	6.6	6.9	12.4	11.9	15.5	10.5	5.2	12.8	15.1	0.125
3.7	7.0	4.5	4.9	6.0	6.8	4.8	6.2	12.5	9.9	0.250
12.2	14.1	18.3	11.8	7.7	19.2	11.6	9.8	9.0	8.2	1.000
11.4	21.8	16.7	15.4	5.8	17.3	16.7	12.8	9.5	9.7	2.000
6.4	18.8	18.0	14.8	6.6	12.6	17.8	8.2	14.0	18.5	6.000
4.9	5.6	7.3	16.5	8.9	4.5	10.1	6.9	13.5	11.1	9.000
4.6	7.0	2.9	6.0	7.4	7.0	5.2	5.0	8.3	3.0	13.000
6.1	4.3	9.0	8.6	5.0	3.9	5.3	6.4	5.8	3.2	16.000
7.1	3.7	4.6	6.5	4.1	6.0	3.4	22.1	4.6	5.5	20.000
5.0	2.4	3.9	6.6	7.4	5.7	4.5	6.5	2.8	7.6	23.000
6.0	4.1	8.6	7.2	3.6	4.4	3.3	4.9	4.9	8.1	27.000
8.3	5.9	7.3	9.0	3.0	9.9	3.3	4.5	3.6	4.4	30.000

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K62

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
3	5	9	5	11	21	13	11	9	11	0.000
12	14	8	4	0	10	22	20	8	10	0.021
10	22	6	2	18	48	20	18	26	48	0.042
18	30	14	0	6	26	28	6	34	26	0.063
6	-2	12	-2	4	44	36	14	32	44	0.125
9	1	5	1	7	7	19	17	5	7	0.250
1	3	7	-7	-1	9	1	-1	17	-1	1.000
-1	1	-5	1	7	-3	9	-3	15	7	2.000
7	-1	3	-11	5	5	-3	5	3	-5	6.000
5	-3	1	-13	3	13	-5	3	-9	3	9.000
2	4	-2	-6	0	0	2	0	-2	0	13.000
2	4	-2	-6	0	0	2	0	-2	0	16.000
0	2	-4	-8	-2	-2	0	8	-4	-2	20.000
8	0	4	-10	-4	-4	-2	6	4	6	23.000
6	-2	2	-12	4	4	6	4	2	4	27.000
3	5	-1	-15	1	1	3	1	-1	1	30.000
4	1	0	-12	-1	-1	1	4	0	2	PTS (dB)
18	30	14	5	18	48	36	20	34	48	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K115

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
1	3	5	-3	-3	-1	5	7	-1	3	0.000
10	22	14	6	-4	38	14	6	8	12	0.021
9	11	13	5	5	17	33	5	7	11	0.042
8	9	2	4	4	26	12	24	16	10	0.063
7	-1	11	3	-7	15	11	13	5	9	0.125
6	18	10	12	12	14	10	22	34	28	0.250
15	27	49	1	11	53	-1	11	13	-2	1.000
1	-7	38	17	-3	19	5	-3	19	3	2.000
-2	20	42	24	14	16	42	-6	16	40	6.000
-1	1	3	7	5	7	-7	5	17	1	9.000
3	15	-3	-1	19	11	-3	9	11	5	13.000
-8	4	16	18	-2	0	-4	8	10	4	16.000
-9	-7	5	7	-3	-1	5	57	-1	13	20.000
0	2	4	6	16	-2	4	6	-2	18	23.000
-6	6	-12	0	0	12	-2	0	12	16	27.000
-10	2	4	6	6	8	4	-4	-2	-8	30.000
-6	1	1	5	5	5	3	15	2	4	PTS (dB)
15	27	49	24	19	53	42	57	34	40	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K69

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
6	4	10	24	23	12	12	0	2	0	0.000
4	2	8	12	11	0	0	-2	10	-2	0.021
2	10	6	10	19	8	8	6	8	6	0.042
0	-2	4	18	17	16	6	4	6	4	0.063
8	6	12	26	25	4	14	12	14	2	0.125
15	13	9	13	12	21	21	9	21	19	0.250
33	31	17	21	20	19	29	27	19	17	1.000
24	52	18	42	11	40	40	28	30	28	2.000
15	43	19	23	22	31	21	19	41	29	6.000
13	11	7	11	10	9	19	17	29	27	9.000
11	-1	5	9	8	7	7	15	17	5	13.000
9	-3	3	7	6	5	5	3	5	3	16.000
7	-5	1	5	4	3	3	1	3	1	20.000
5	3	-1	3	2	11	1	-1	1	-1	23.000
3	1	-3	1	10	9	-1	7	-1	-3	27.000
1	-1	-5	9	8	7	-3	-5	7	5	30.000
4	-1	-2	4	6	7	0	0	2	0	PTS (dB)
33	52	19	42	25	40	40	28	41	29	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K114

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
-2	2	4	0	2	-2	10	-3	8	7	0.000
16	10	2	8	10	6	18	5	6	5	0.021
4	8	20	6	28	24	26	23	24	23	0.042
12	6	18	14	16	22	34	21	22	11	0.063
10	14	6	22	14	20	12	19	10	19	0.125
8	2	4	10	12	8	10	7	8	7	0.250
6	0	2	-2	10	6	-2	5	6	5	1.000
-6	-2	0	6	-2	4	6	3	4	3	2.000
2	-4	-2	-6	6	2	-6	1	2	1	6.000
0	4	-4	2	4	0	2	-1	0	-1	9.000
-3	1	3	9	1	-3	-1	6	-3	6	13.000
-4	0	2	-2	0	6	8	-5	-4	5	16.000
-6	-2	0	6	7	-6	6	3	4	3	20.000
2	-4	-2	4	6	2	-6	-9	2	1	23.000
0	-6	-4	2	4	0	2	-1	0	-1	27.000
8	-8	-6	0	2	-2	0	-3	-2	-3	30.000
1	-5	-3	3	4	-2	0	-2	1	0	PTS (dB)
16	14	20	22	28	24	34	23	24	23	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA K102

FREQUENCY (kHz)

.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
3	5	11	5	13	11	33	5	1	1	0.000
11	13	9	3	1	9	11	13	-1	10	0.021
-1	1	-3	1	-1	7	-1	11	17	7	0.042
7	-1	5	-1	7	15	7	-1	5	5	0.063
5	7	3	7	5	3	5	7	-7	13	0.125
3	5	11	5	3	1	13	15	1	1	0.250
1	3	-1	13	1	-1	1	3	-1	-1	1.000
9	1	-3	1	9	-3	29	11	17	7	2.000
-3	-1	5	-1	7	-5	7	-1	15	5	6.000
5	-3	-7	-3	-5	3	5	-3	3	13	9.000
3	-5	1	5	3	11	3	5	1	1	13.000
1	-7	-1	3	11	9	11	13	-1	9	16.000
9	1	-3	1	-1	7	-1	1	7	7	20.000
-3	-1	-4	-1	-3	5	-3	9	5	15	23.000
7	-1	5	9	7	5	-3	9	5	-7	27.000
15	7	3	7	5	3	5	7	3	3	30.000
7	2	0	4	2	5	0	7	5	5	PTS (dB)
15	13	11	13	13	15	33	15	17	15	MAXIMUM TS (dB)

INDIVIDUAL THRESHOLD SHIFT (dB)

CHINCHILLA N93

FREQUENCY (kHz)

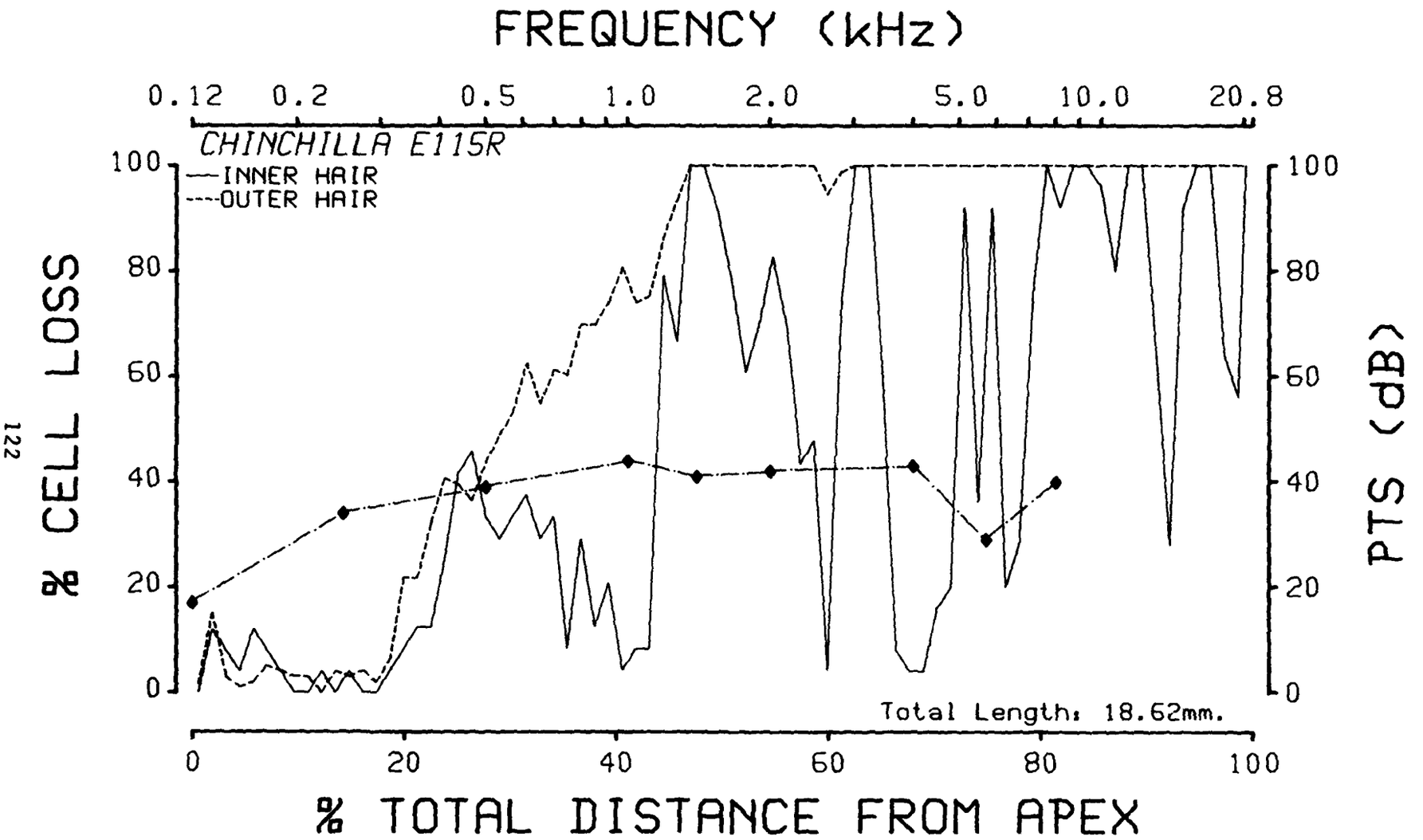
.1250	.2500	.500	1.00	1.40	2.00	2.80	4.00	5.70	8.00	RECOVERY (days)
0	6	21	14	20	25	32	19	42	27	0.000
8	14	9	22	18	32	10	-3	30	35	0.021
6	2	7	0	16	20	18	15	8	14	0.042
4	-3	25	8	4	18	36	33	16	21	0.063
2	-2	23	26	22	6	14	21	4	29	0.125
8	4	-1	12	-2	12	20	7	20	15	0.250
6	2	17	20	6	20	8	5	-2	-7	1.000
-6	0	15	18	4	-2	-4	-7	6	1	2.000
2	-2	-7	6	12	6	13	1	14	-1	6.000
2	8	13	36	22	6	14	1	5	19	9.000
0	6	1	4	10	14	12	9	12	7	13.000
7	2	18	0	6	0	8	5	8	3	16.000
-4	2	7	10	6	10	-2	5	8	3	20.000
-6	0	5	8	4	8	6	3	6	1	23.000
12	-2	13	-4	2	6	4	11	4	-1	27.000
2	8	13	6	2	26	4	1	4	-1	30.000
1	2	10	5	3	12	3	5	5	1	PTS (dB)
12	14	25	36	22	32	36	33	42	35	MAXIMUM TS (dB)

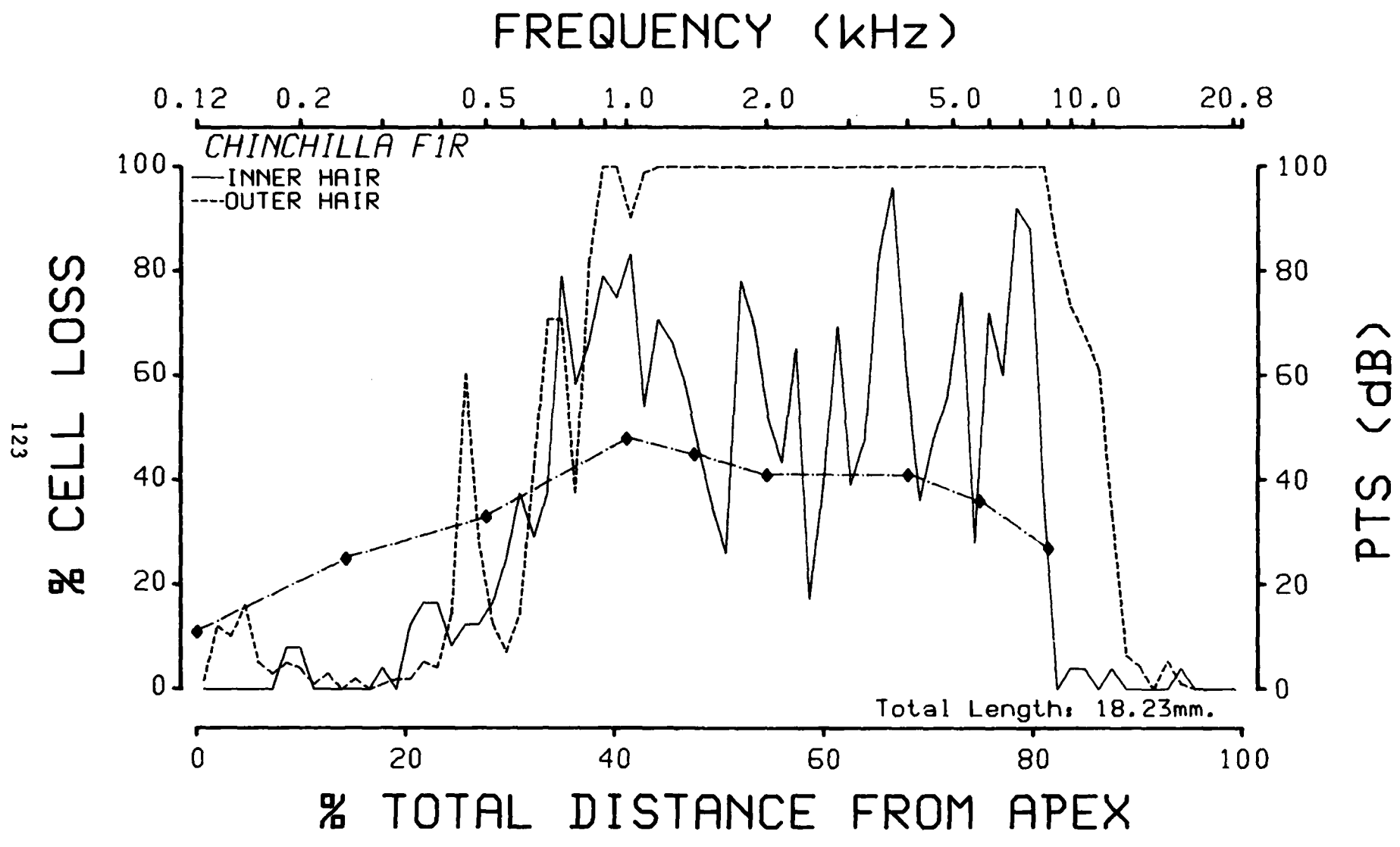
APPENDIX C

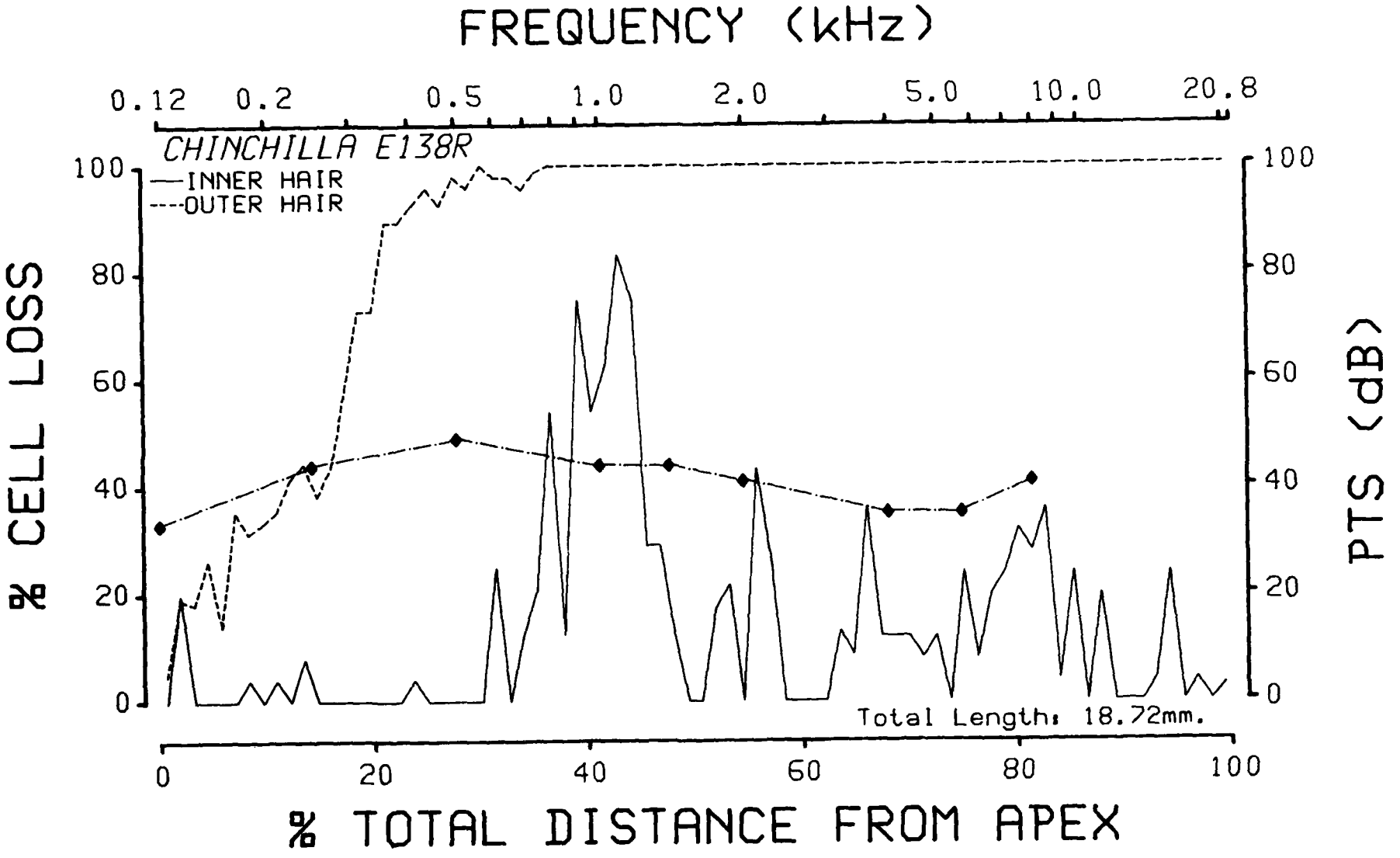
Cochleograms and permanent threshold shifts for each animal used in this study arranged by exposure group.

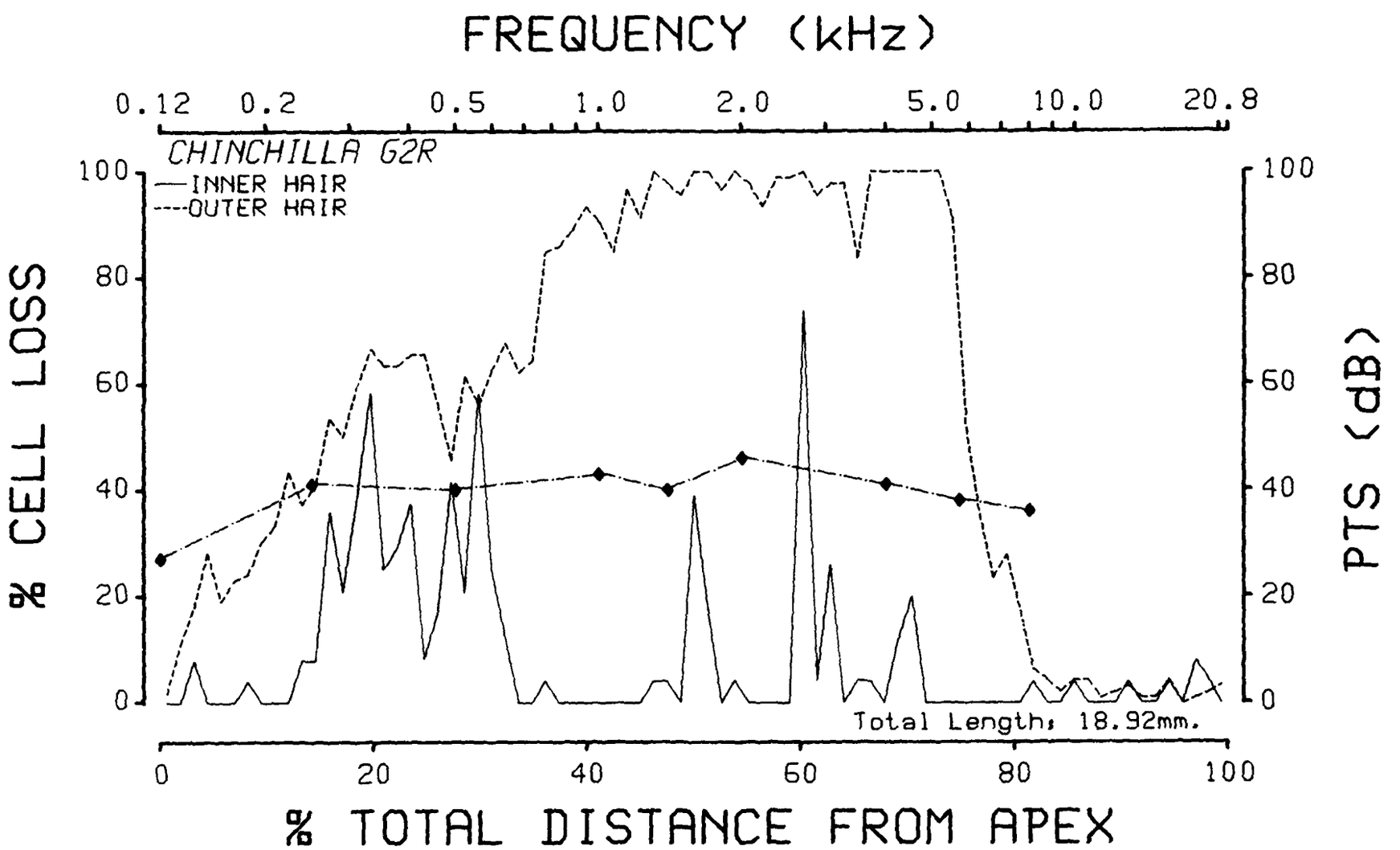
Group 1 - Exposure: 147 dB High peak impulse

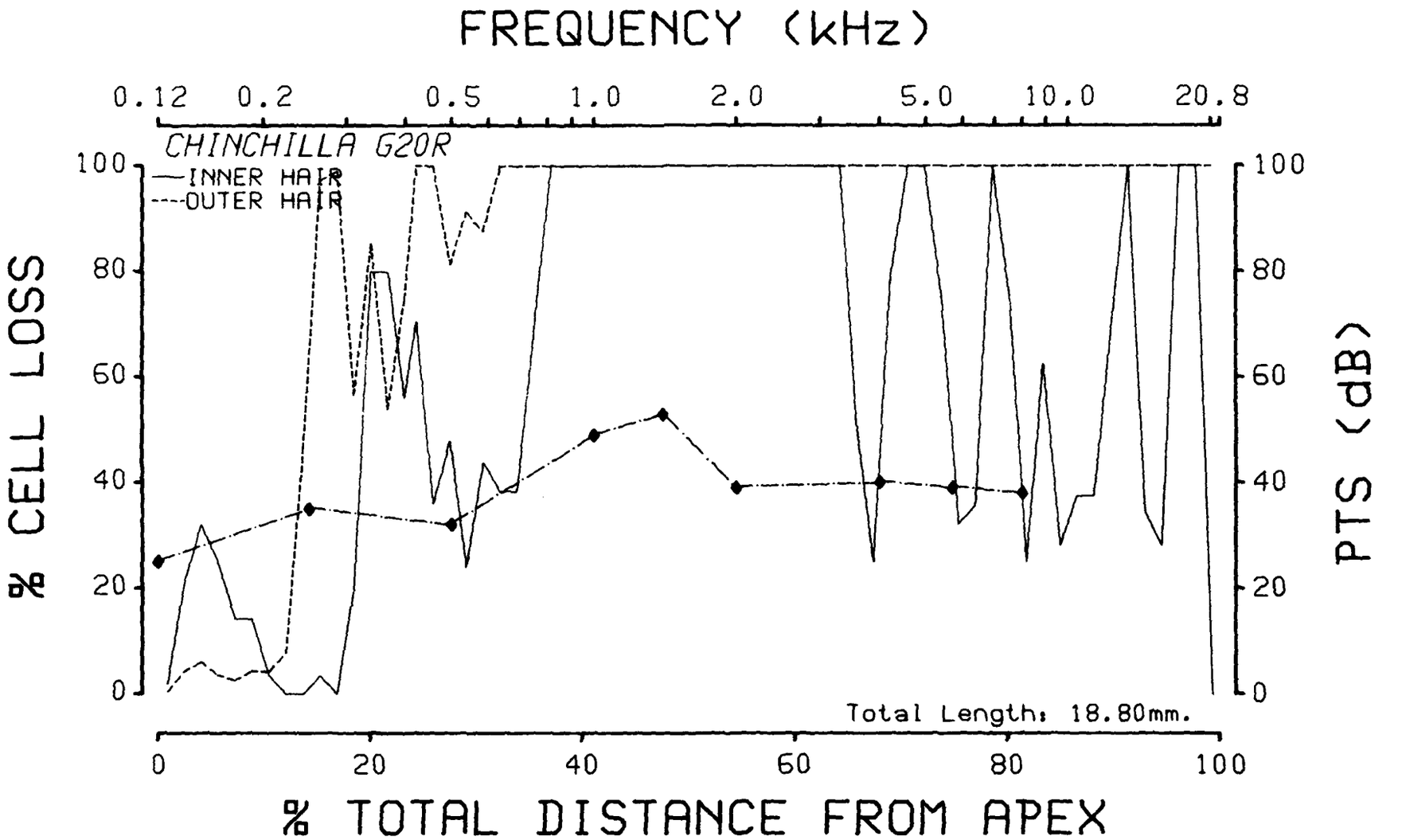
Animals: E115R
F1R
E138R
G2R
G20R
G5R

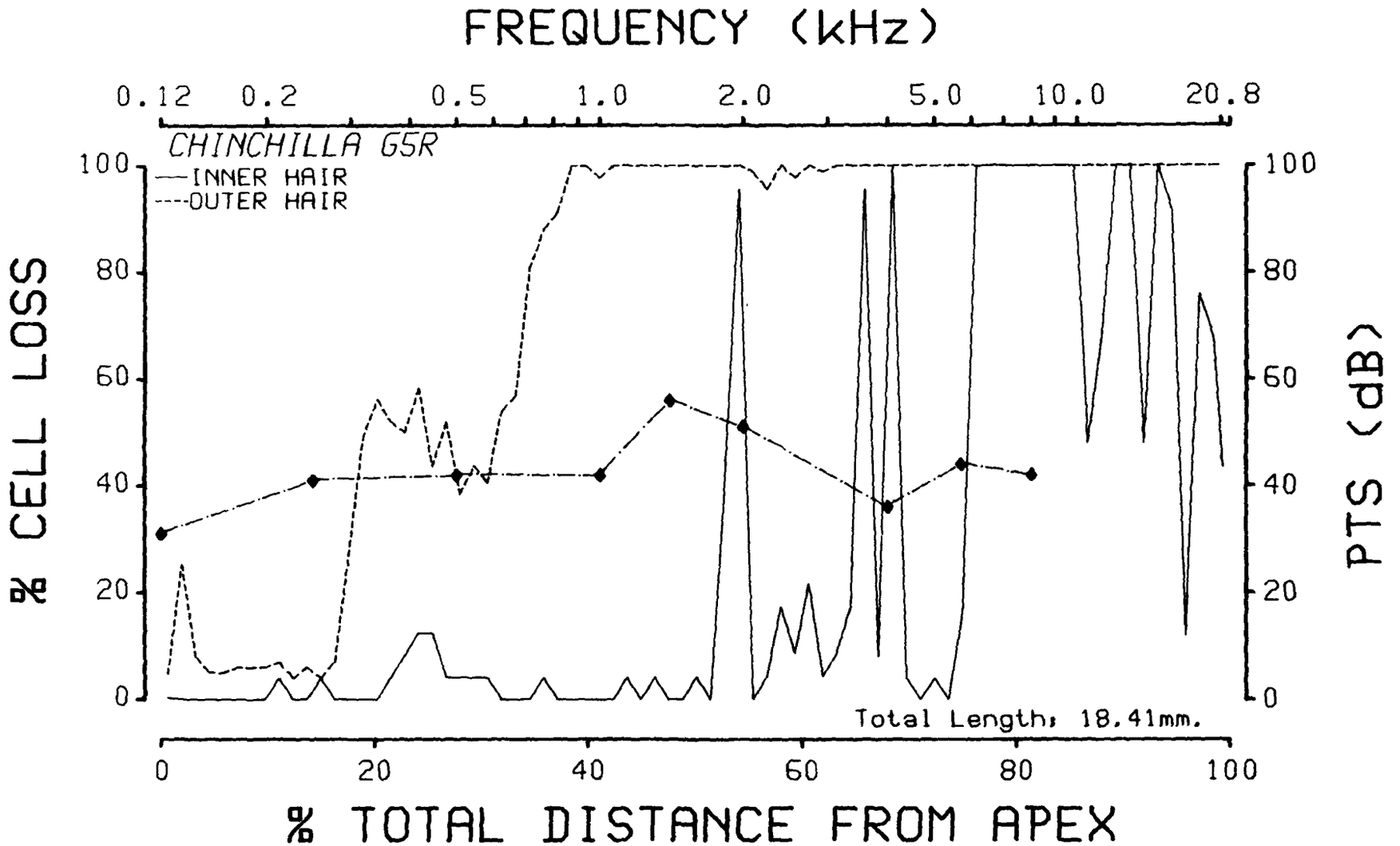

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA E115R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.62mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA F1R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.23mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA E138R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.72mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

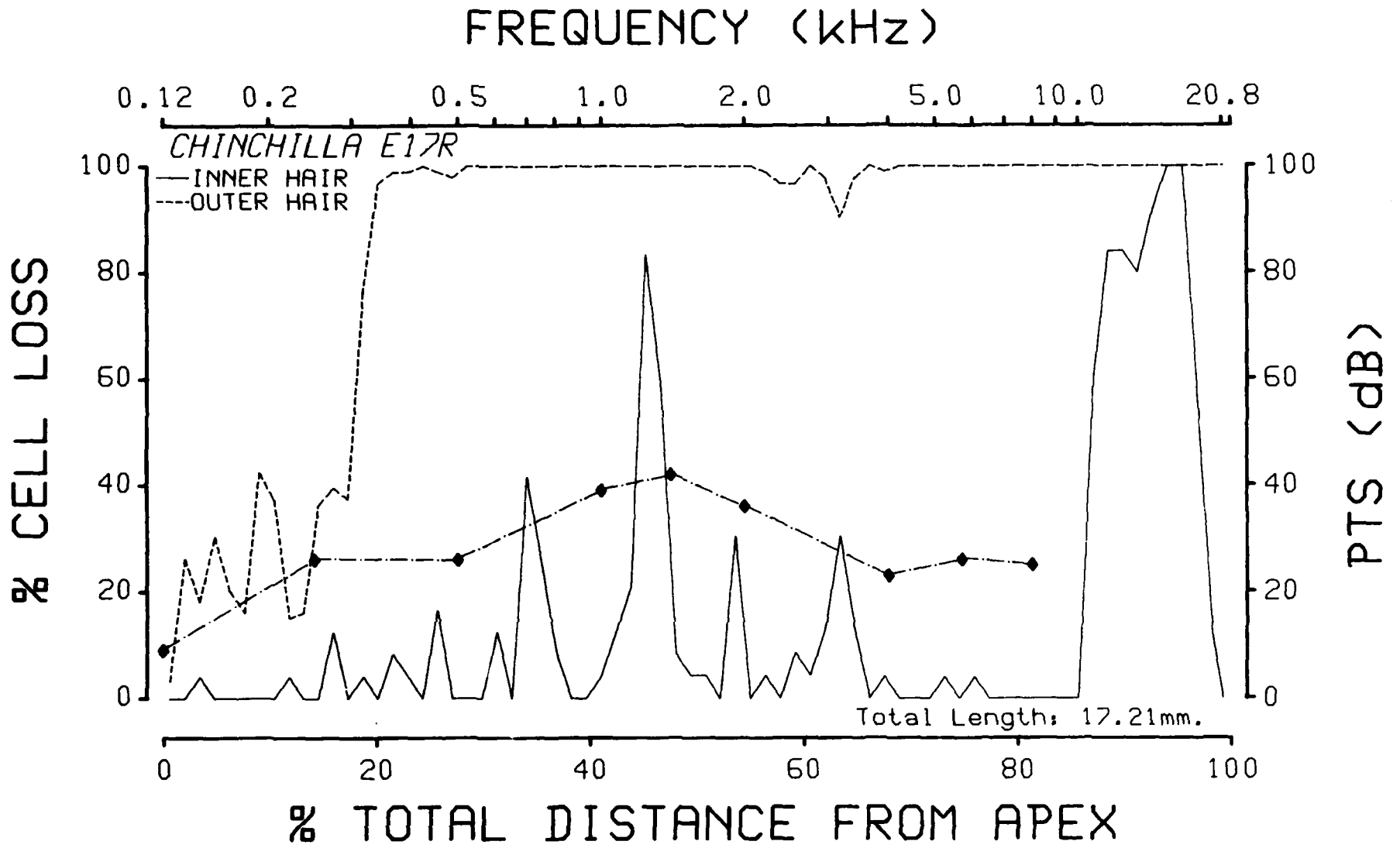

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G2R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.92mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

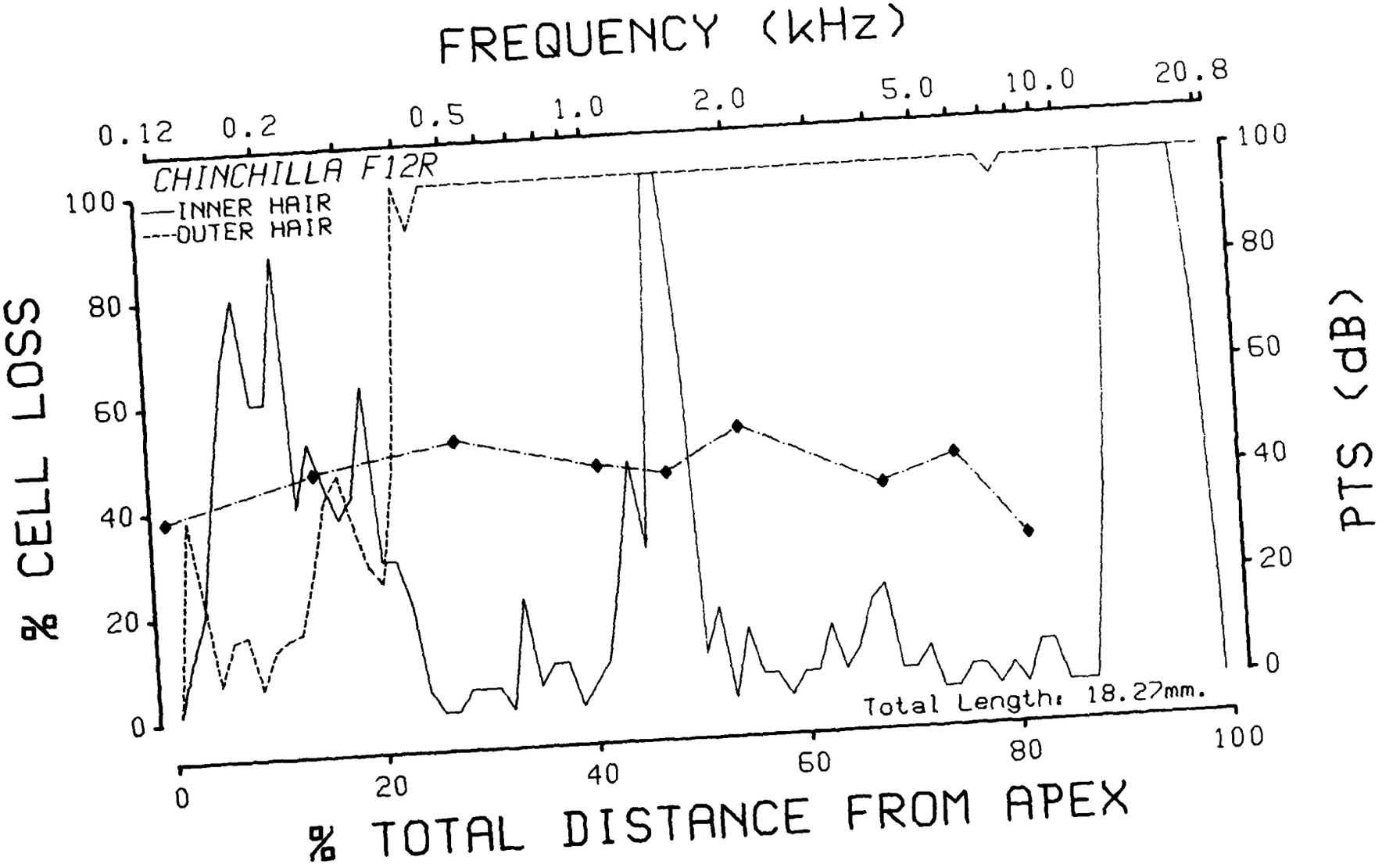

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G20R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.80mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

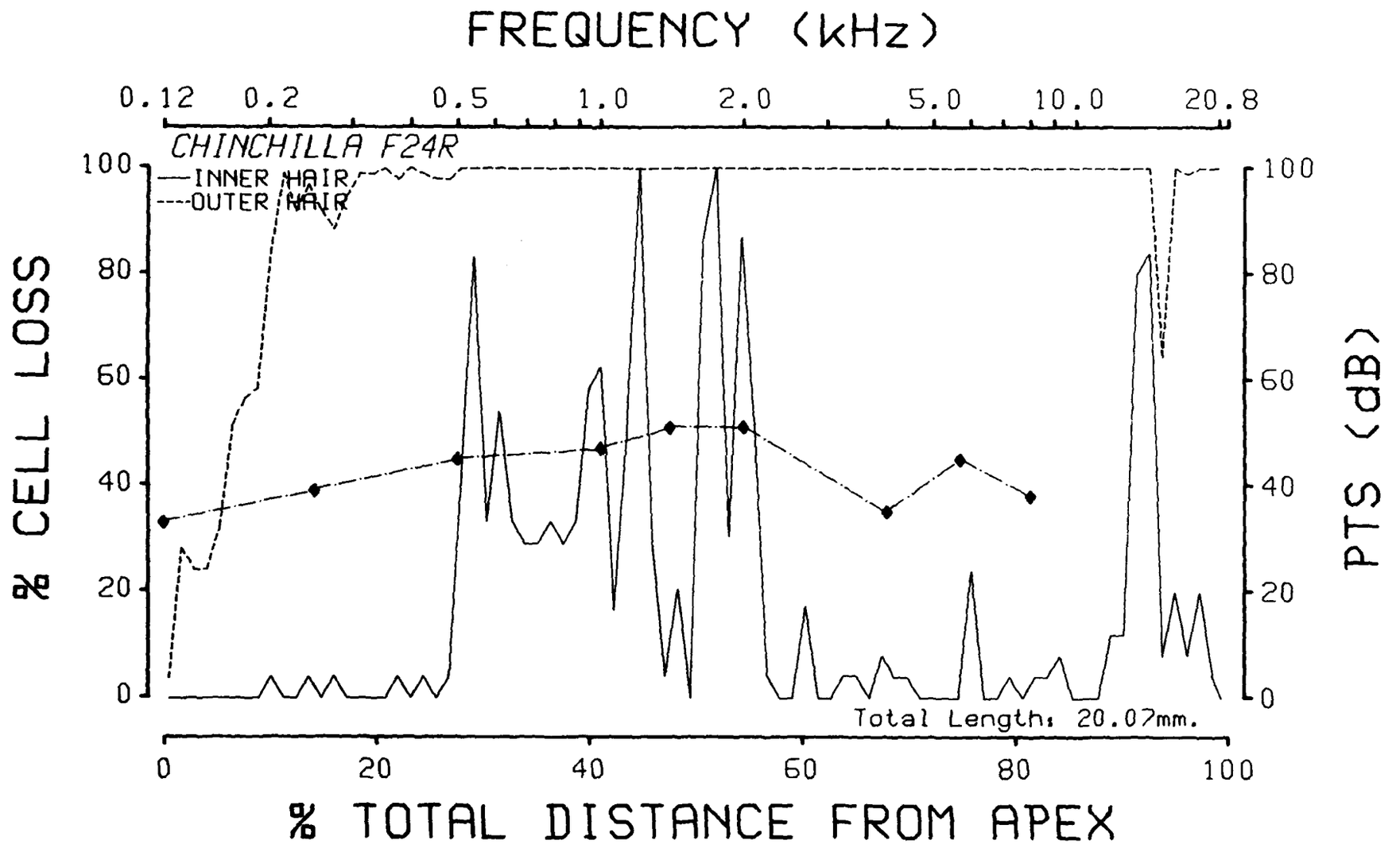

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G5R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.41mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

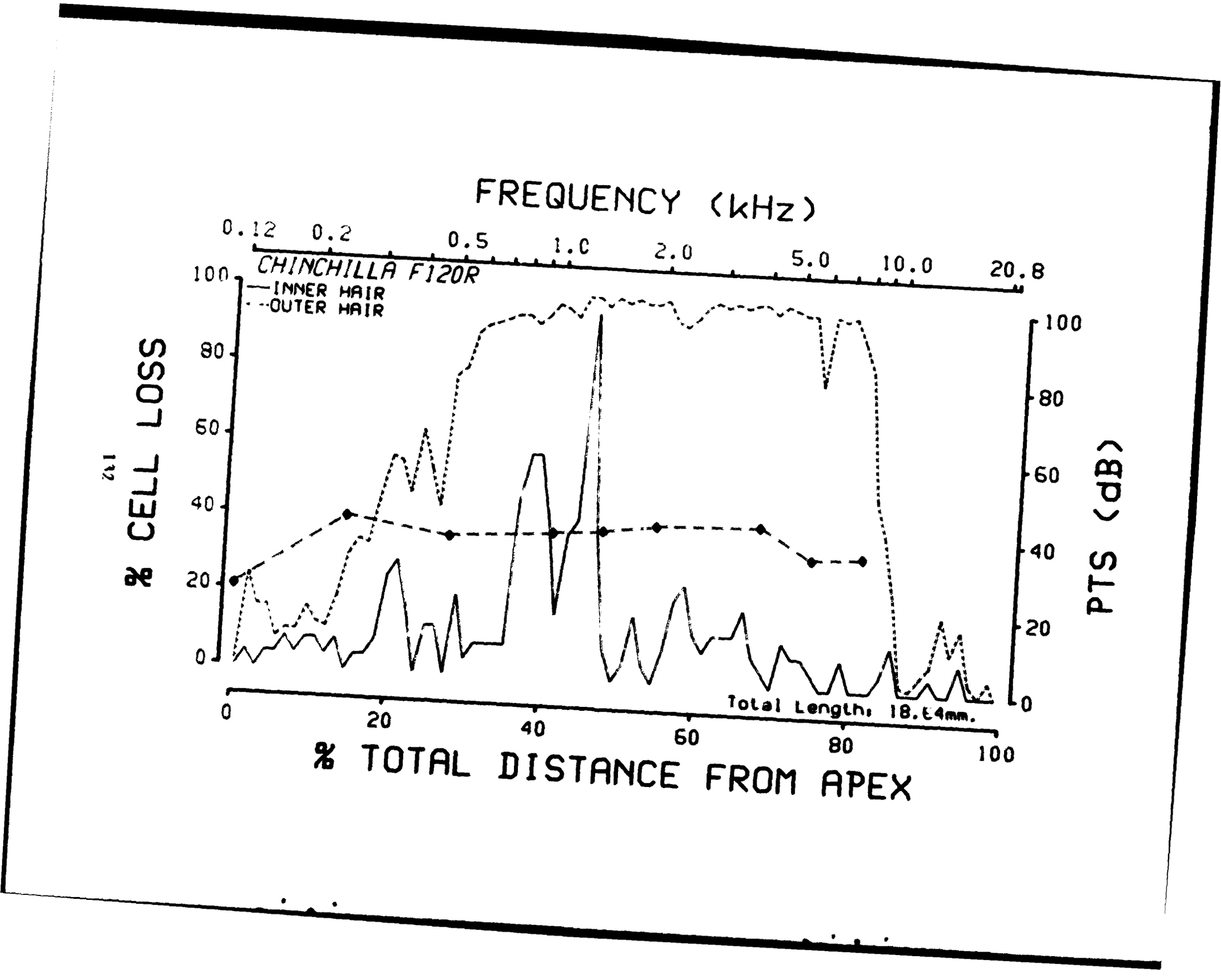
Group 2 - Exposure: 139 dB Low peak impulse

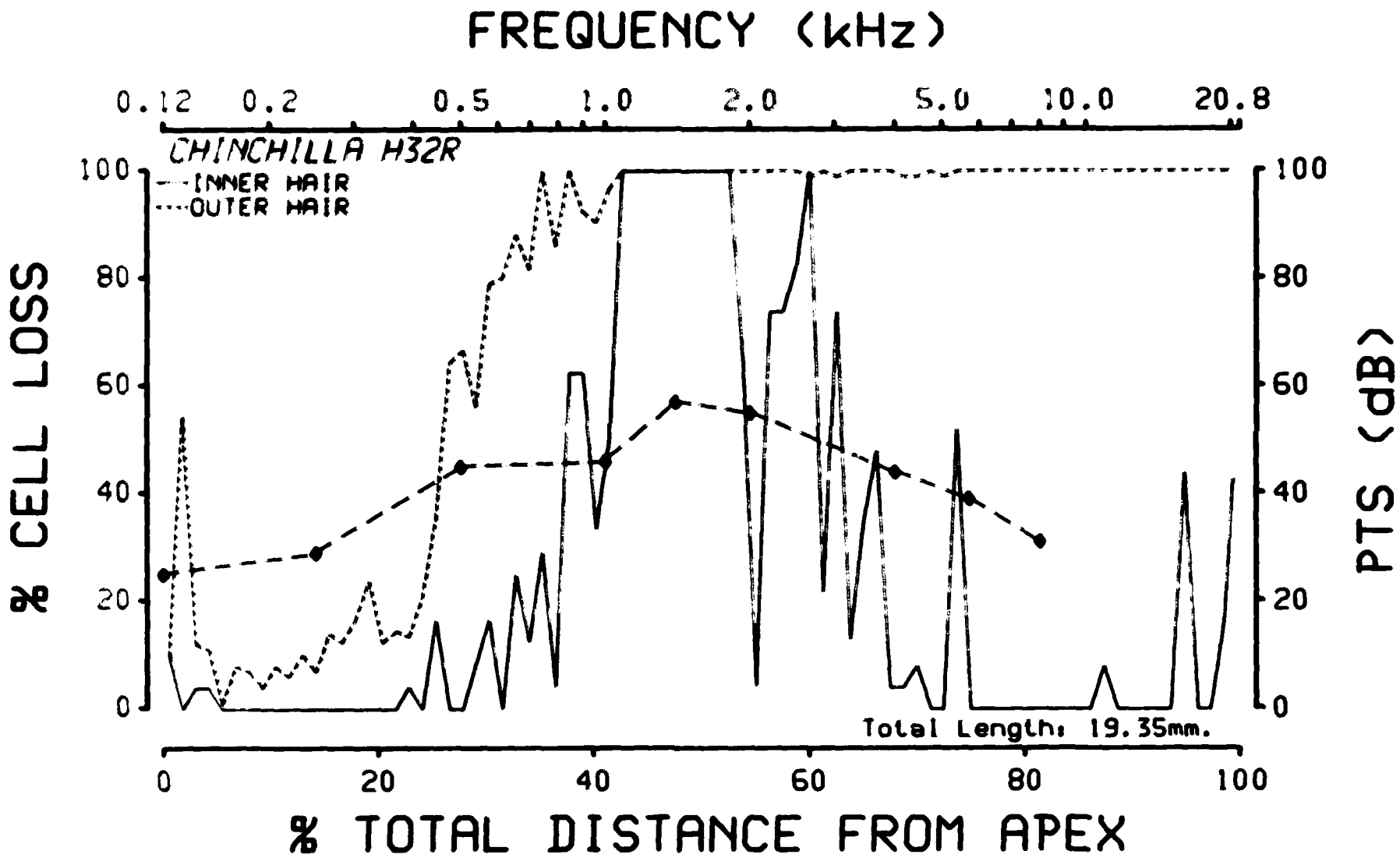
Animals: E17R
F12R
F24R
F120R
H32R
G16R

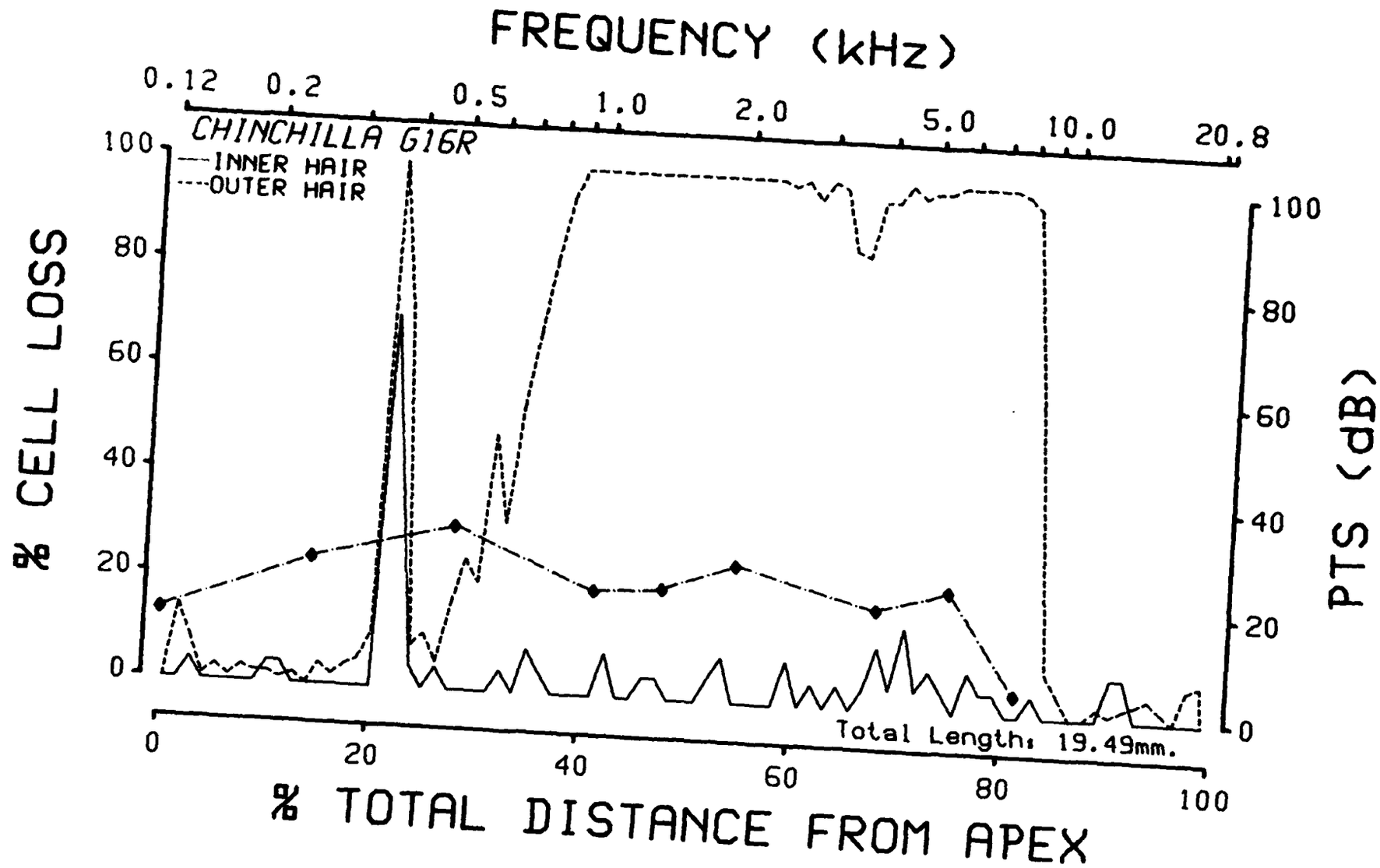

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA E17R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 17.21mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA F12R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.27mm.
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA F24R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 20.07mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

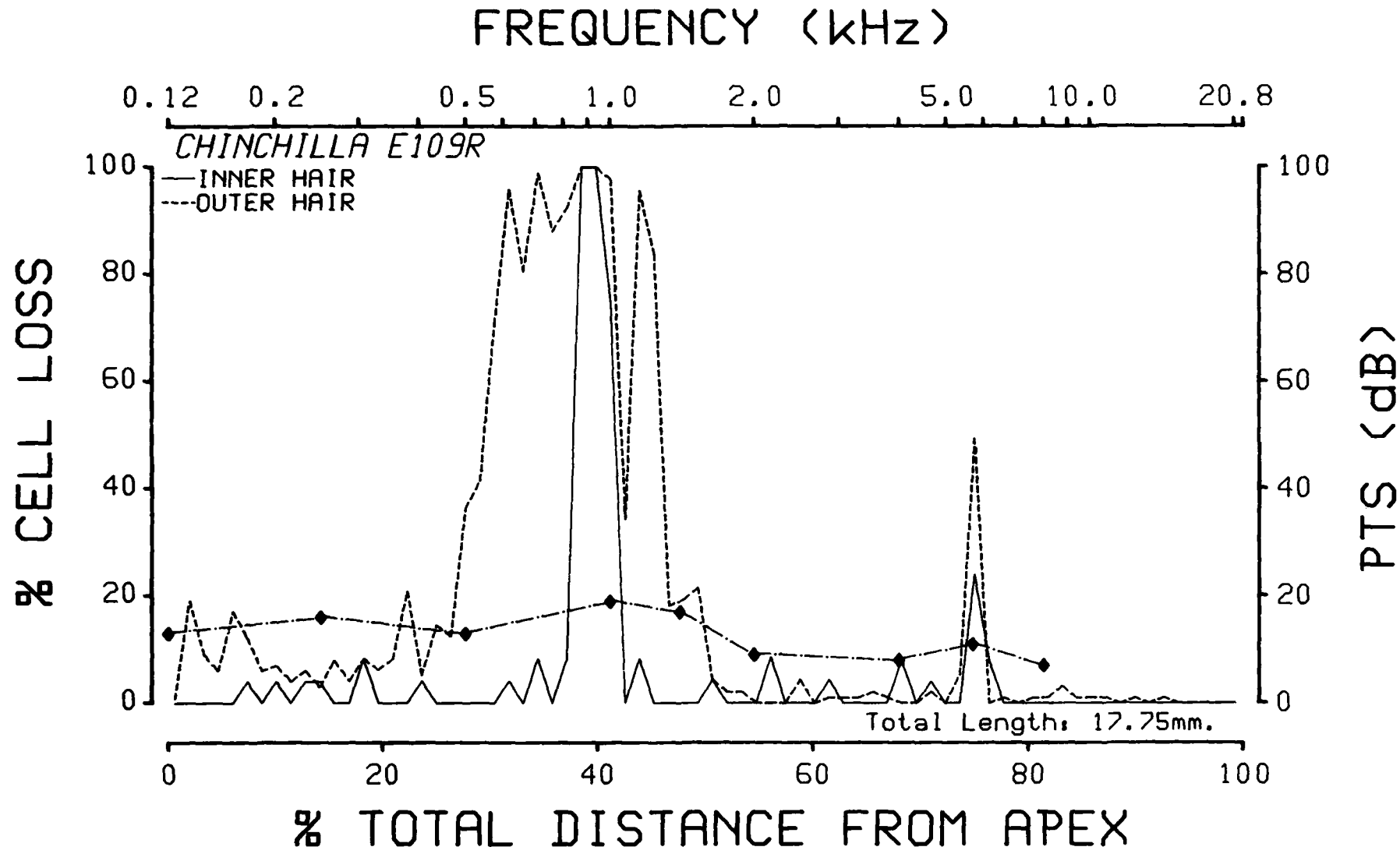

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA F120R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.64mm.
% TOTAL DISTANCE FROM APEX

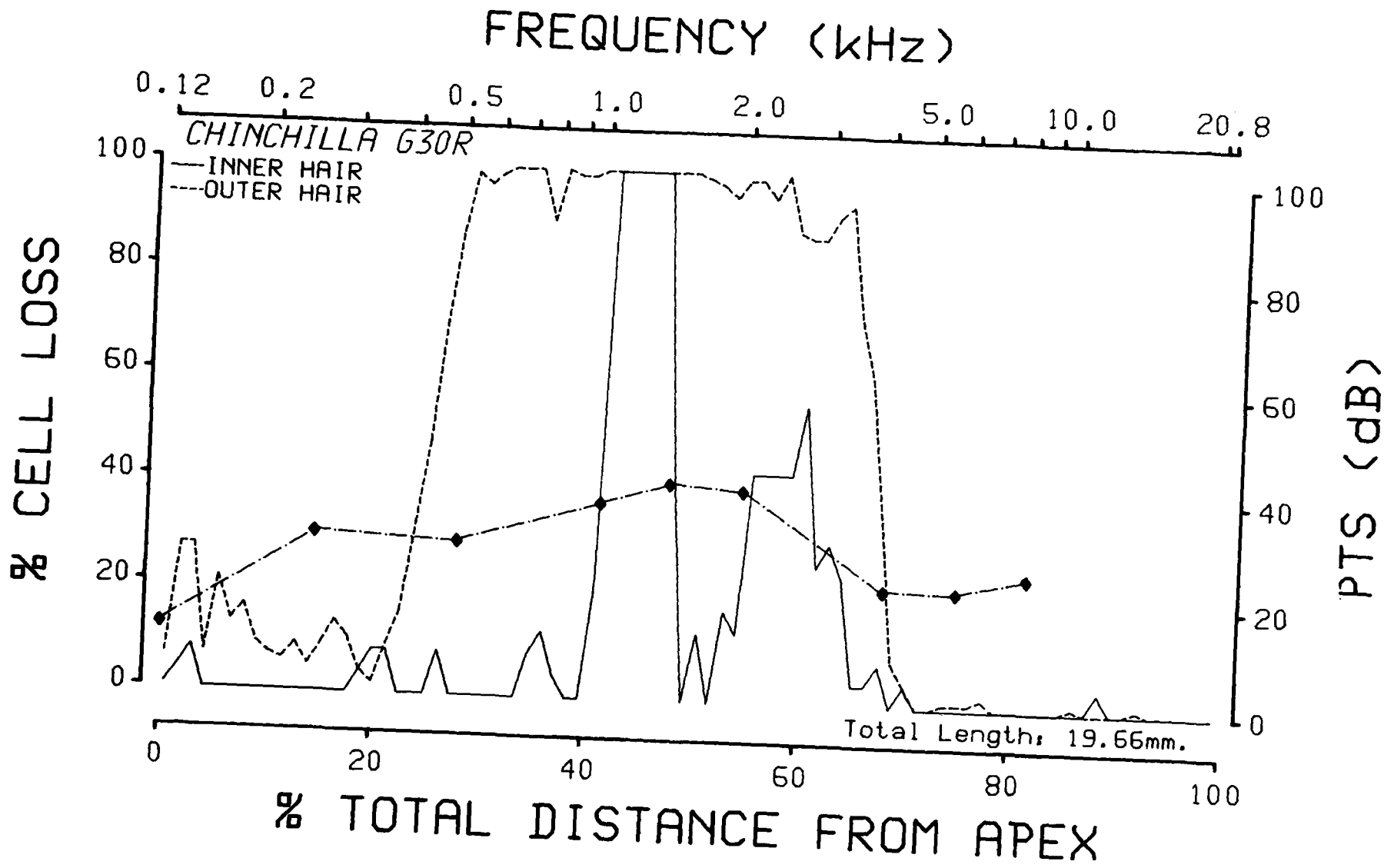

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H32R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.35mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

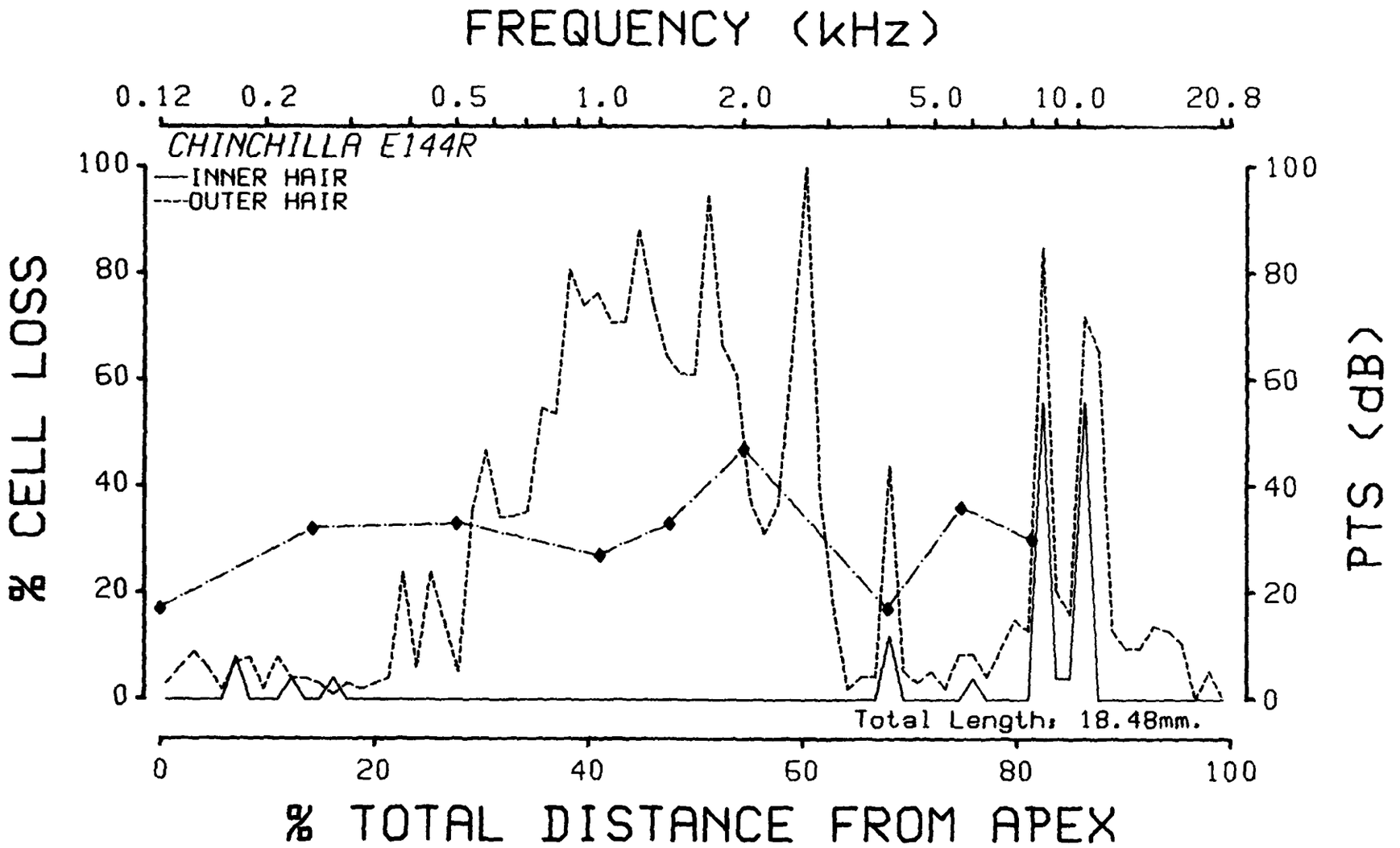

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G16R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.49mm.
% TOTAL DISTANCE FROM APEX

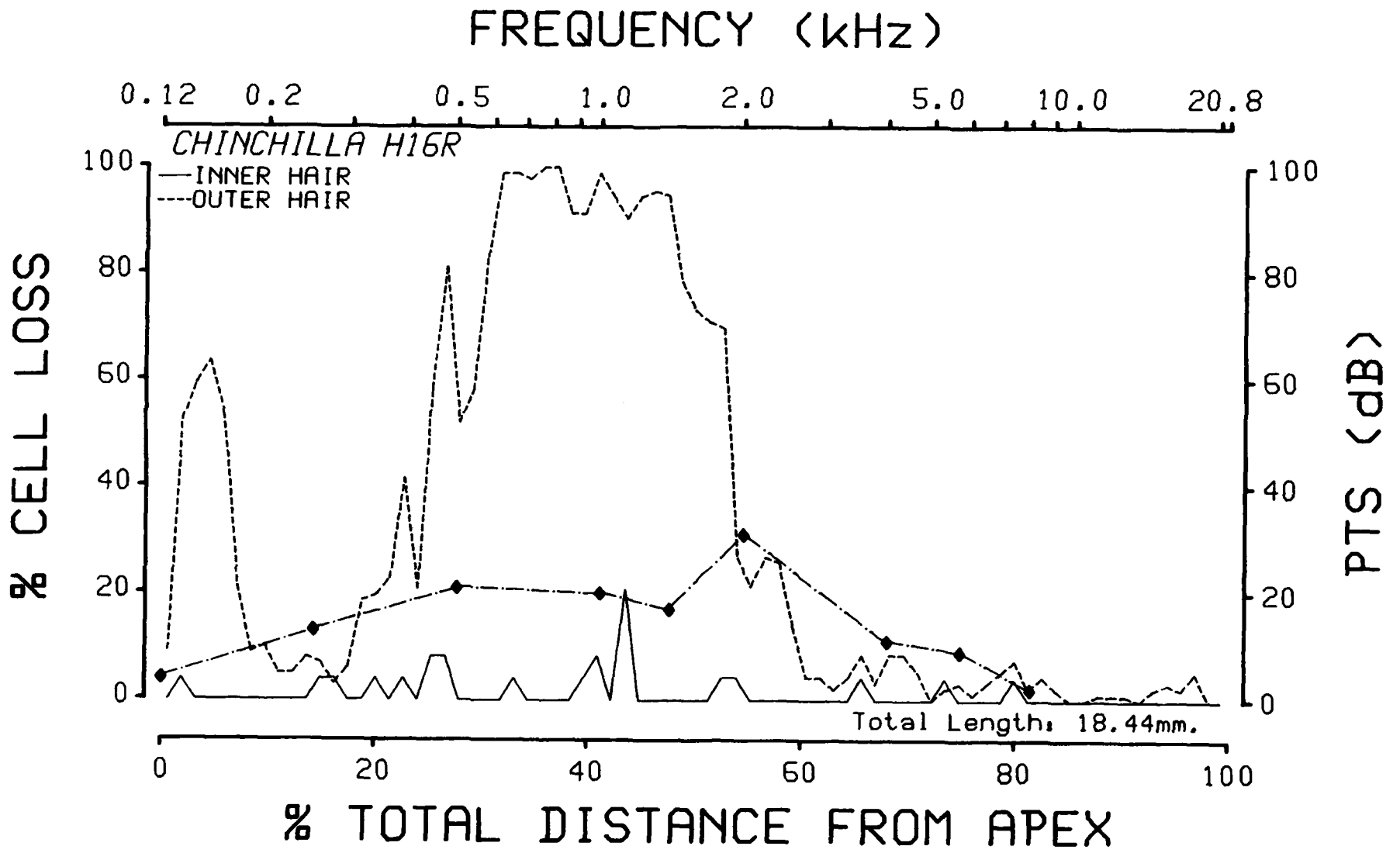
Group 3 - Exposure: 139 dB High peak impulse

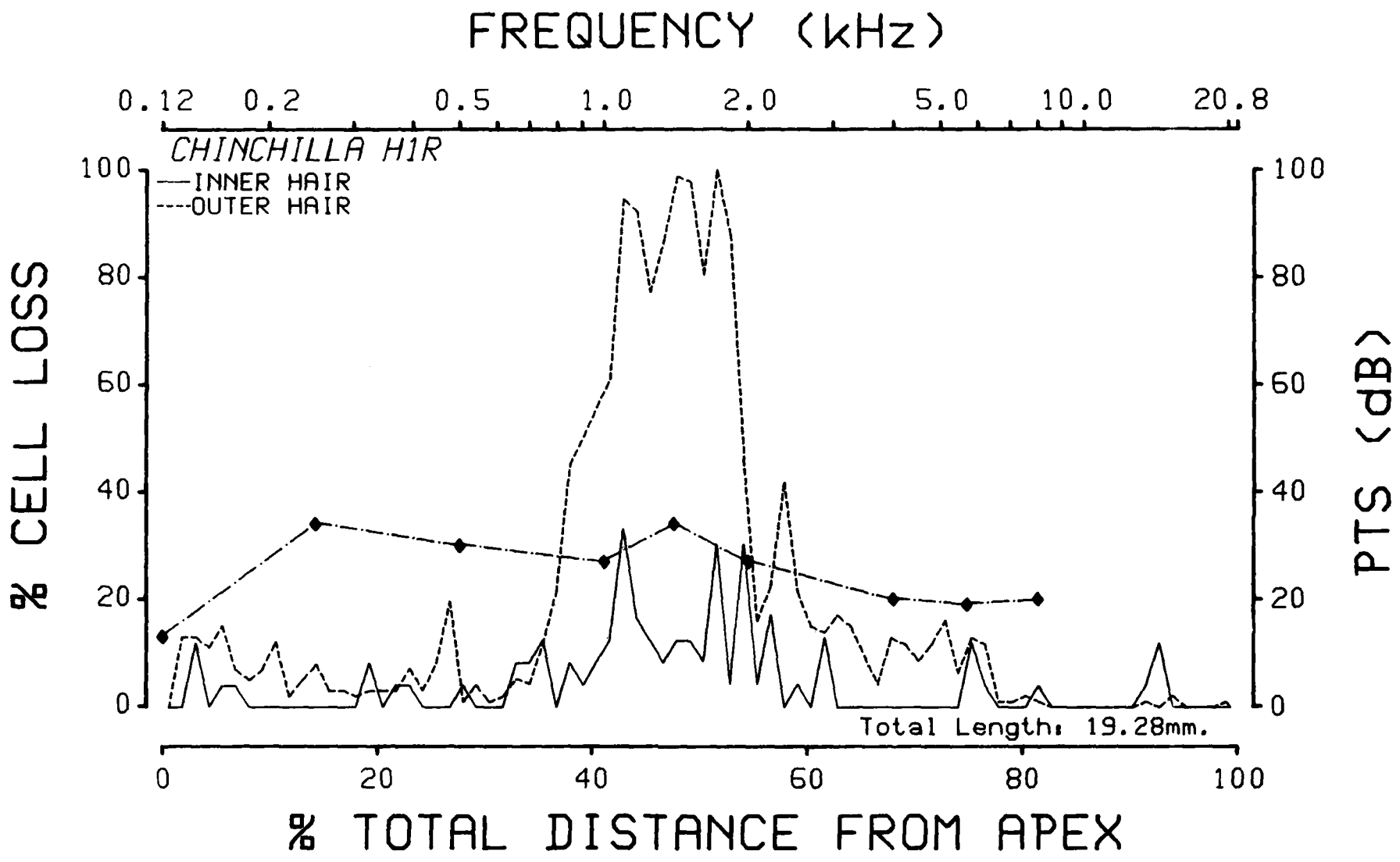
Animals: E109R
G30R
E144R
H16R
H1R
H42R

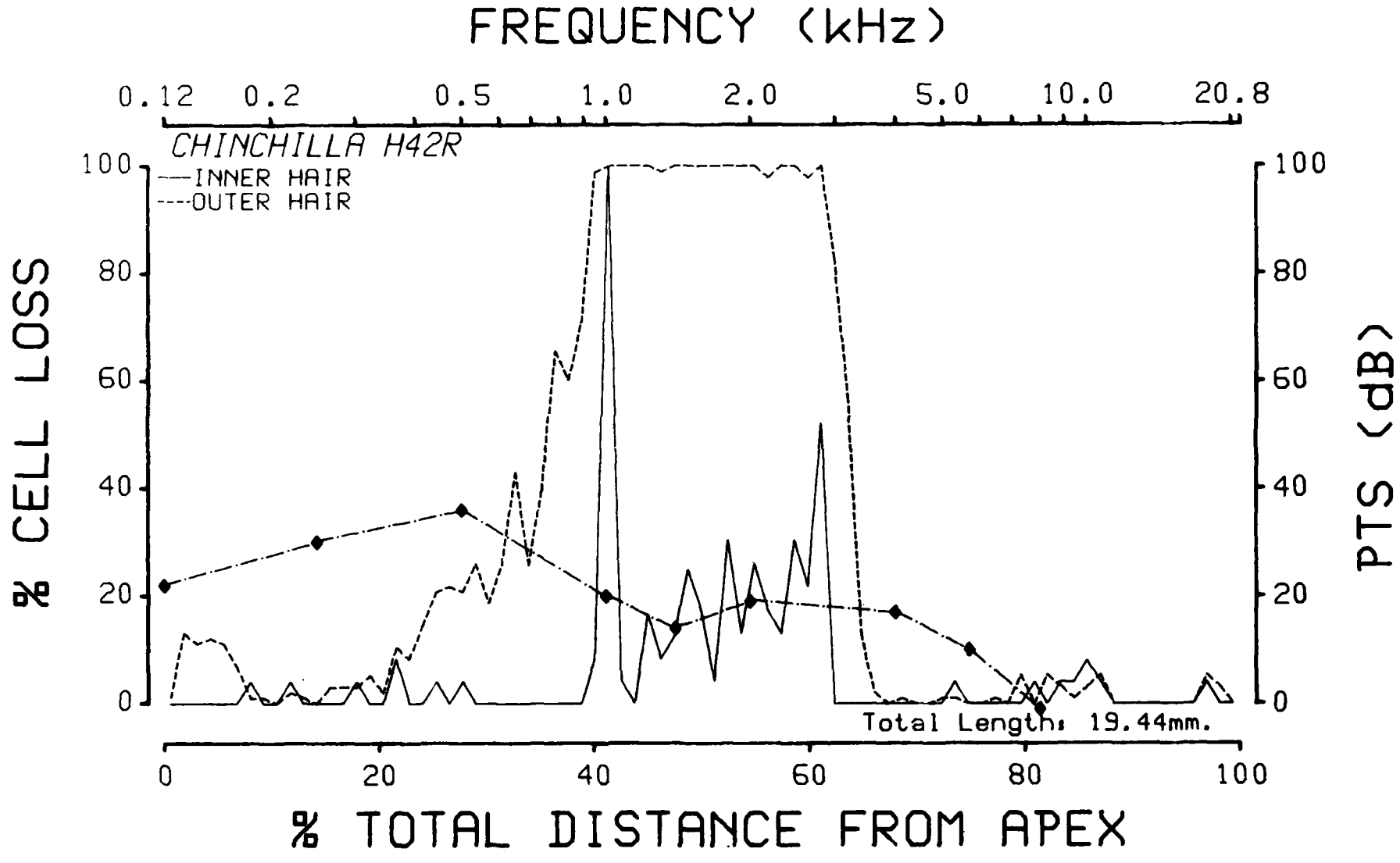

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA E109R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 17.75mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G30R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.66mm.
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA E144R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.48mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

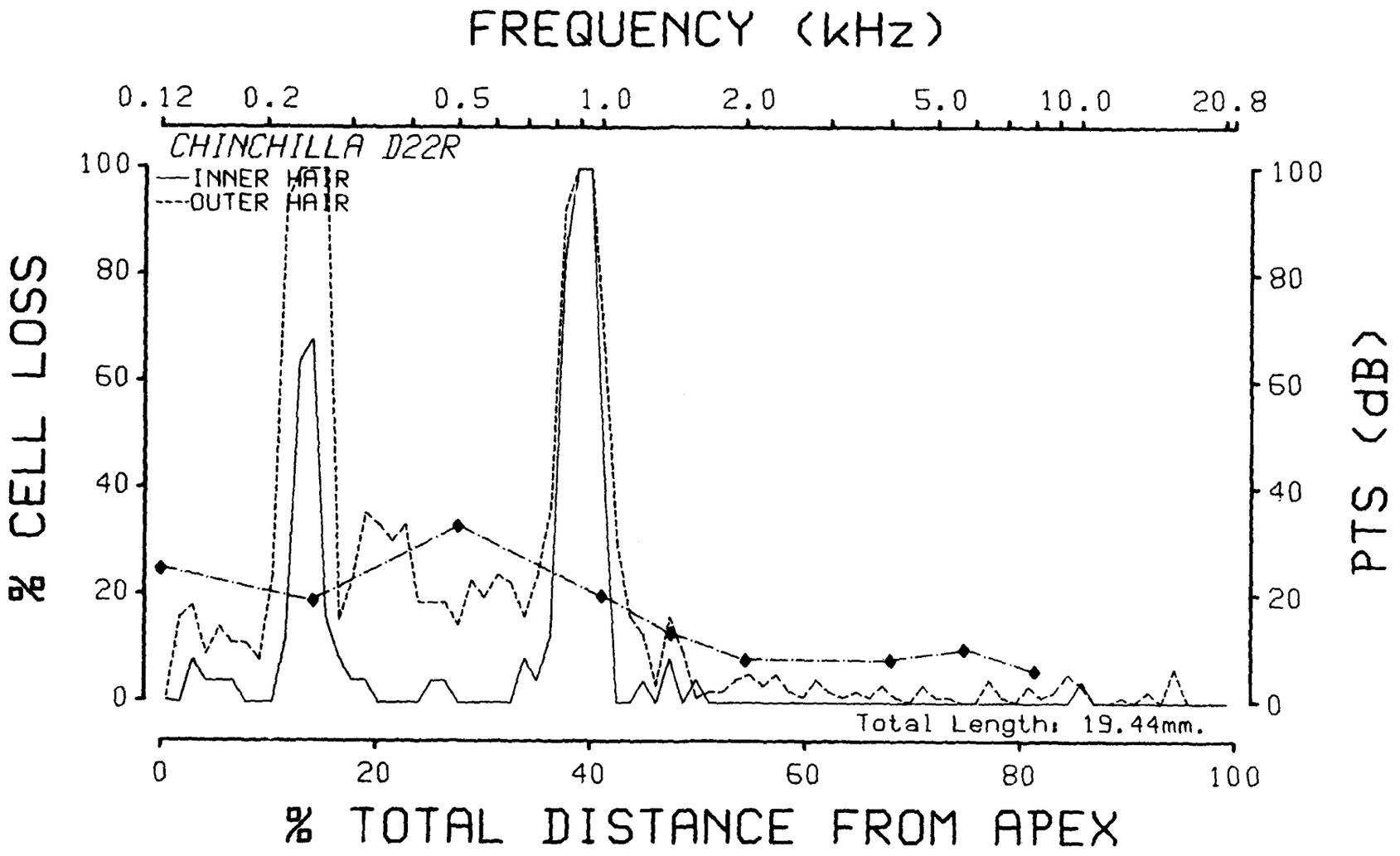

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H16R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.44mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

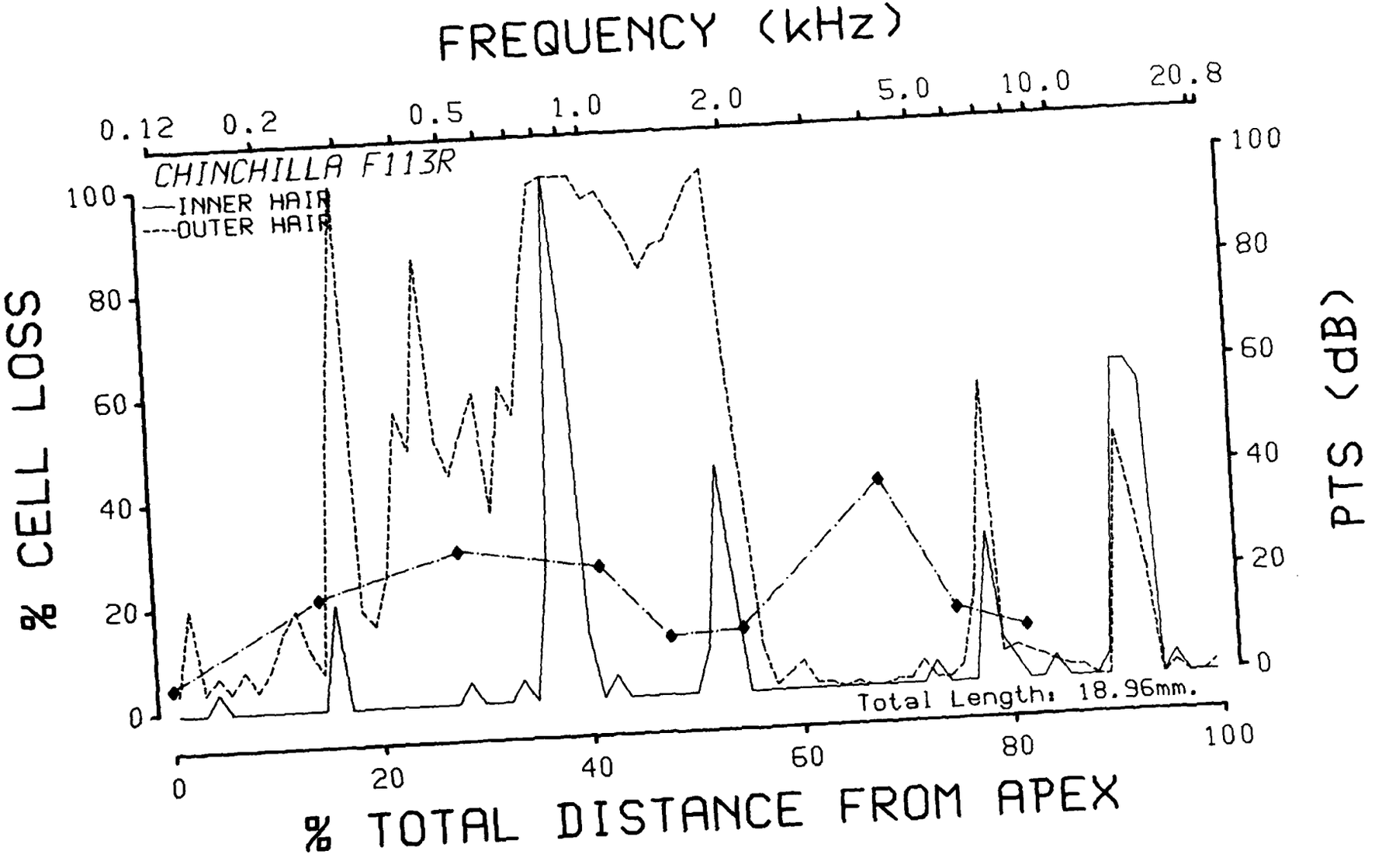

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H1R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.28mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

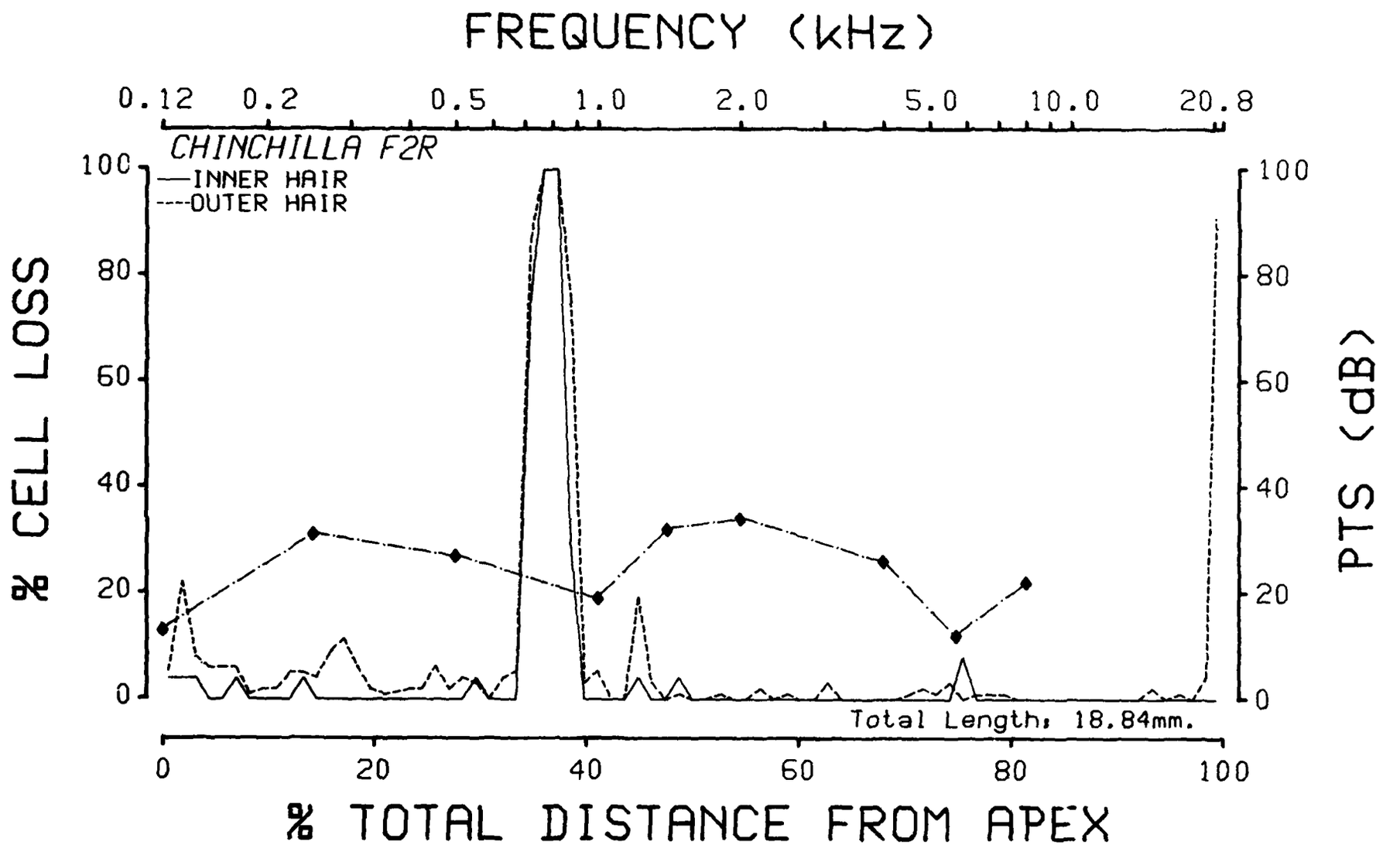

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H42R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.44mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

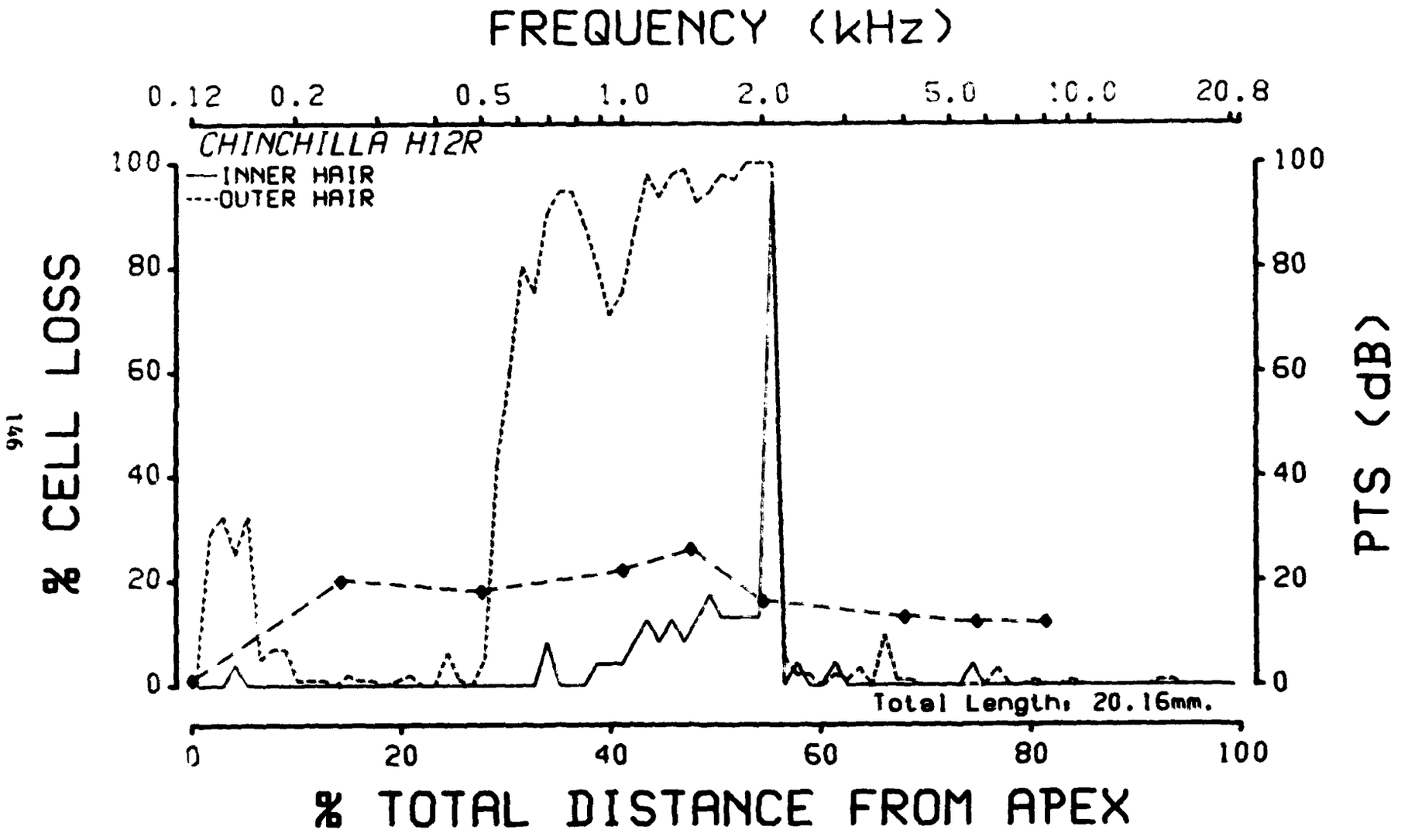
Group 4 - Exposure: 131 dB Low peak impulse

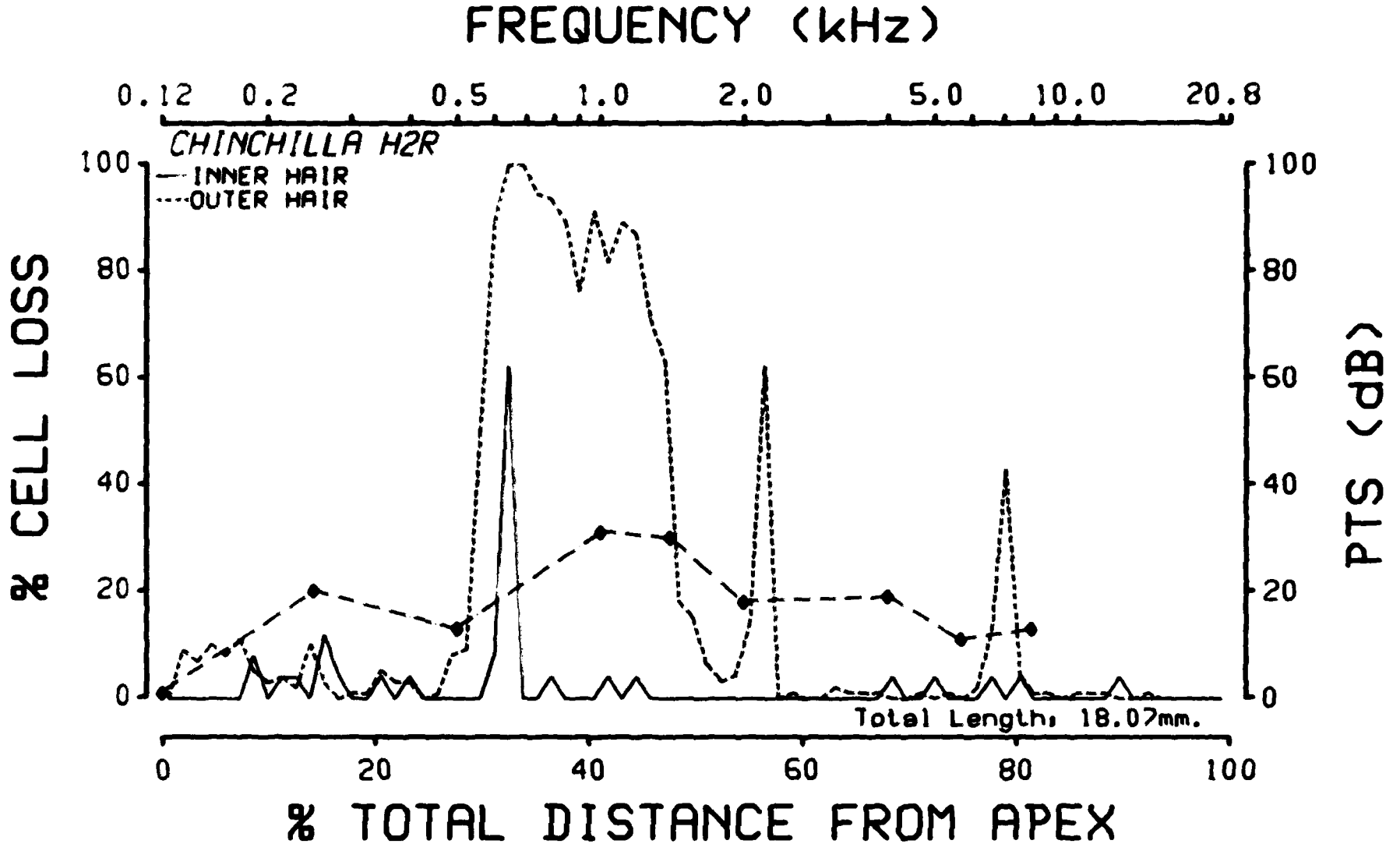
Animals: D22R
F113R
F2R
H12R
H2R
G9R

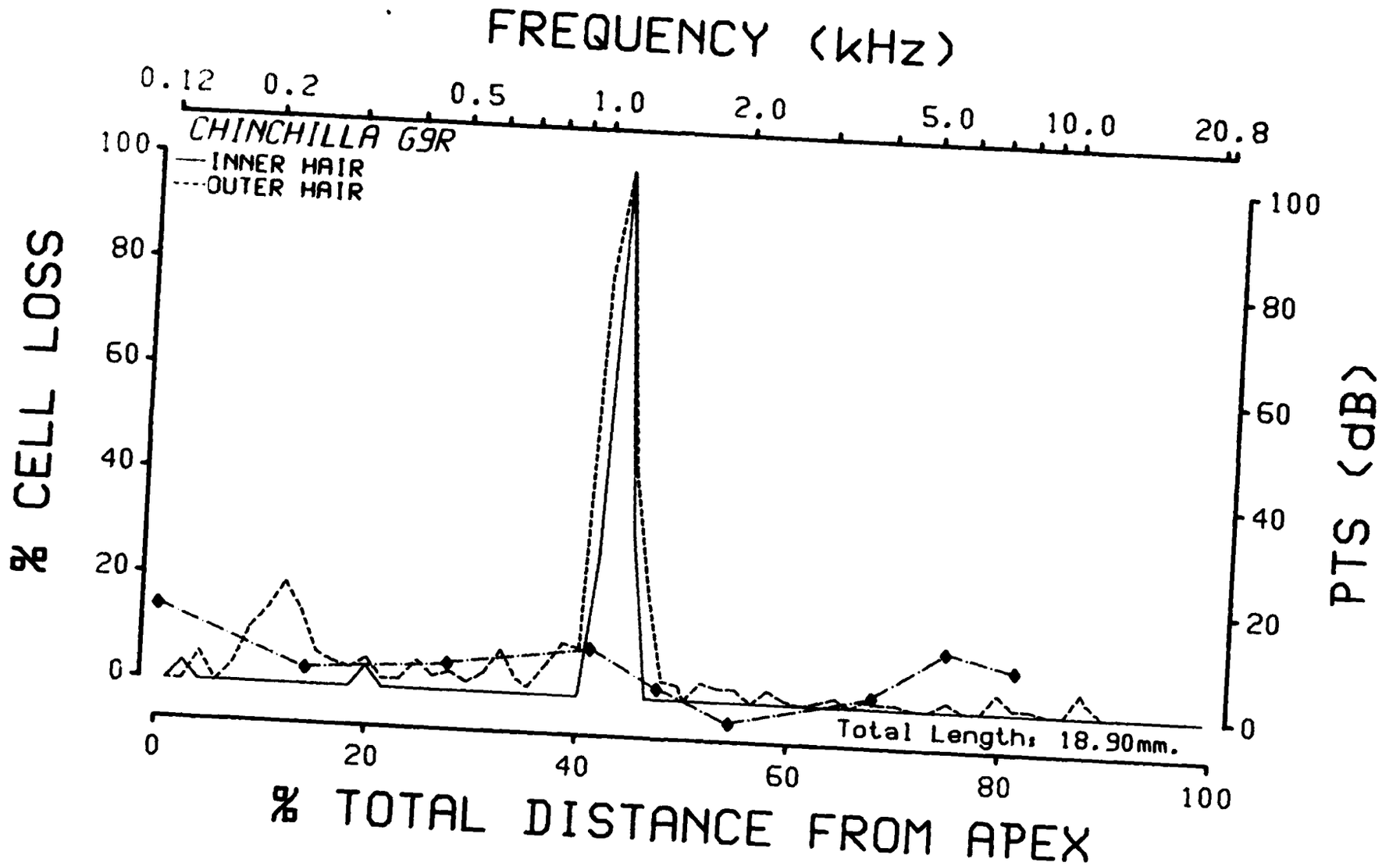

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA D22R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.44mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA F113R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.96mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA F2R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.84mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

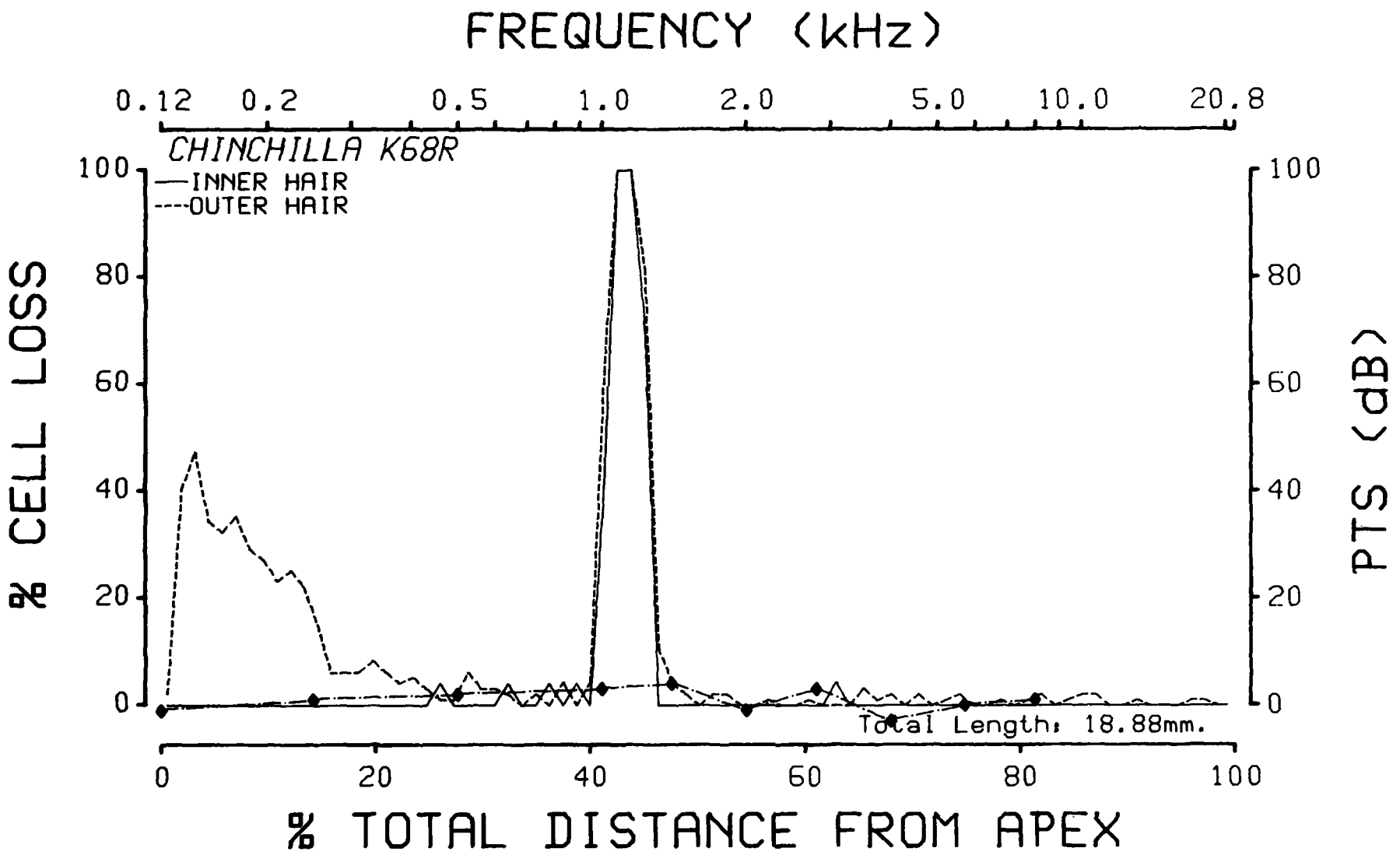

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H12R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 20.16mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

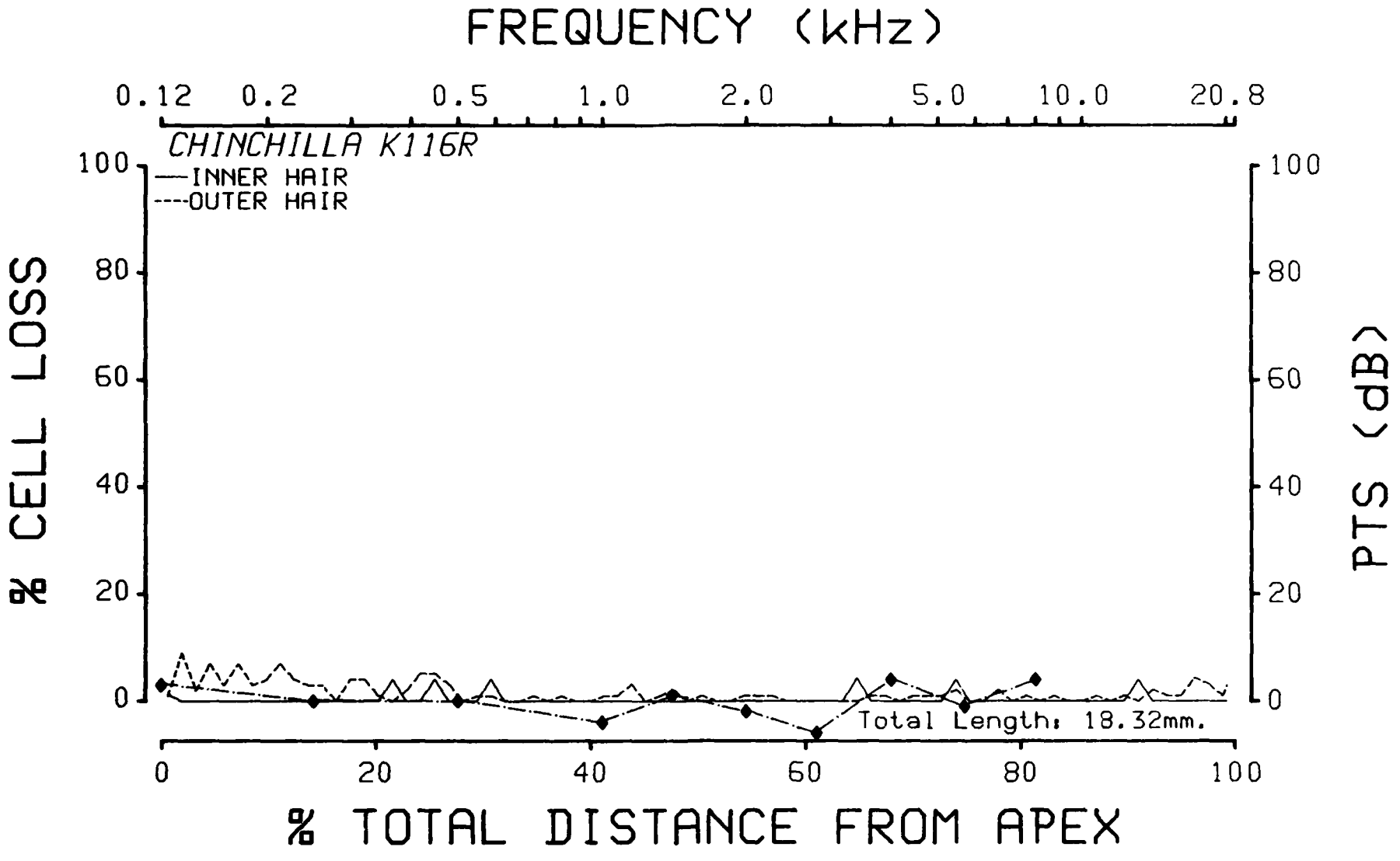

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H2R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.07mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

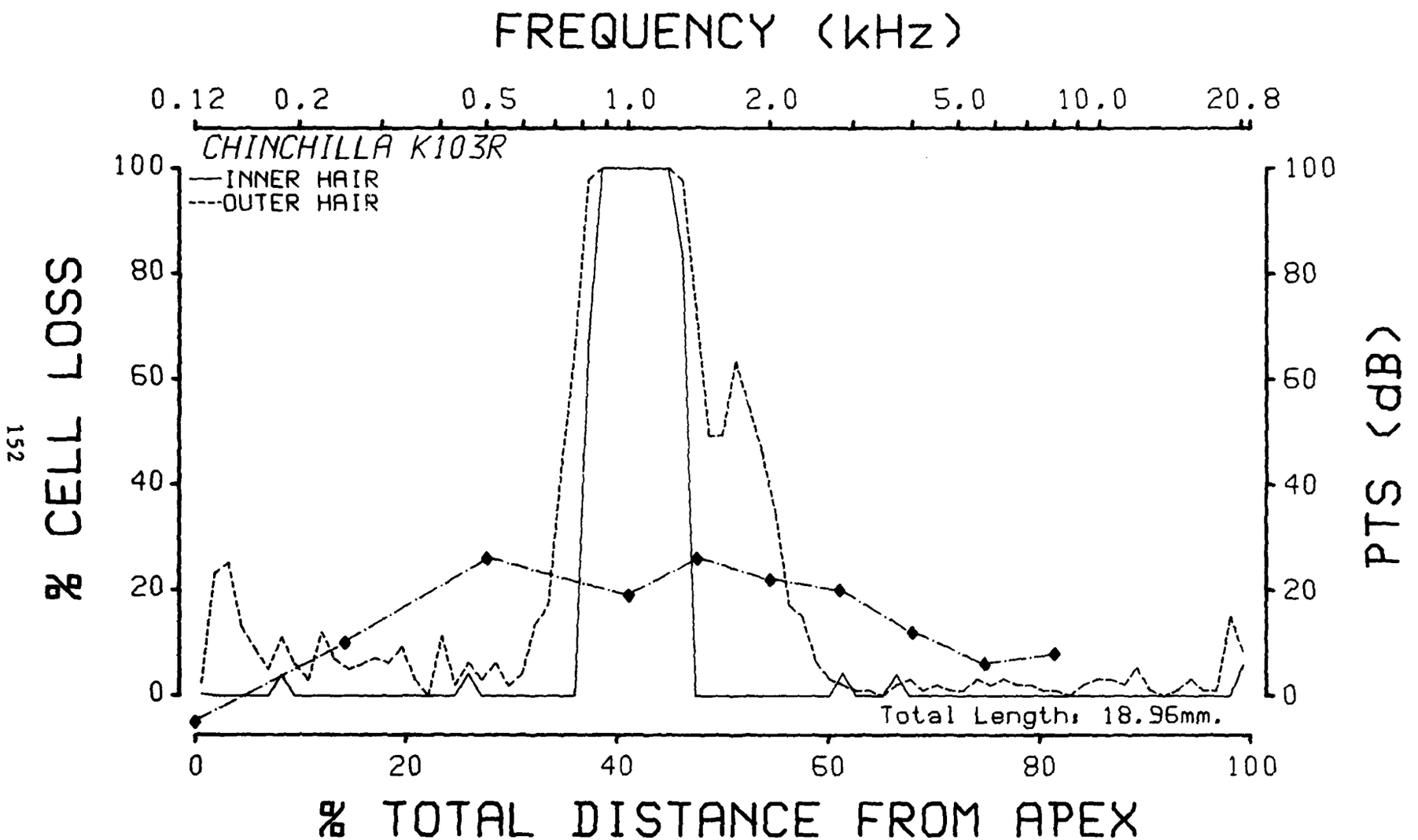

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA G9R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.90mm.
% TOTAL DISTANCE FROM APEX

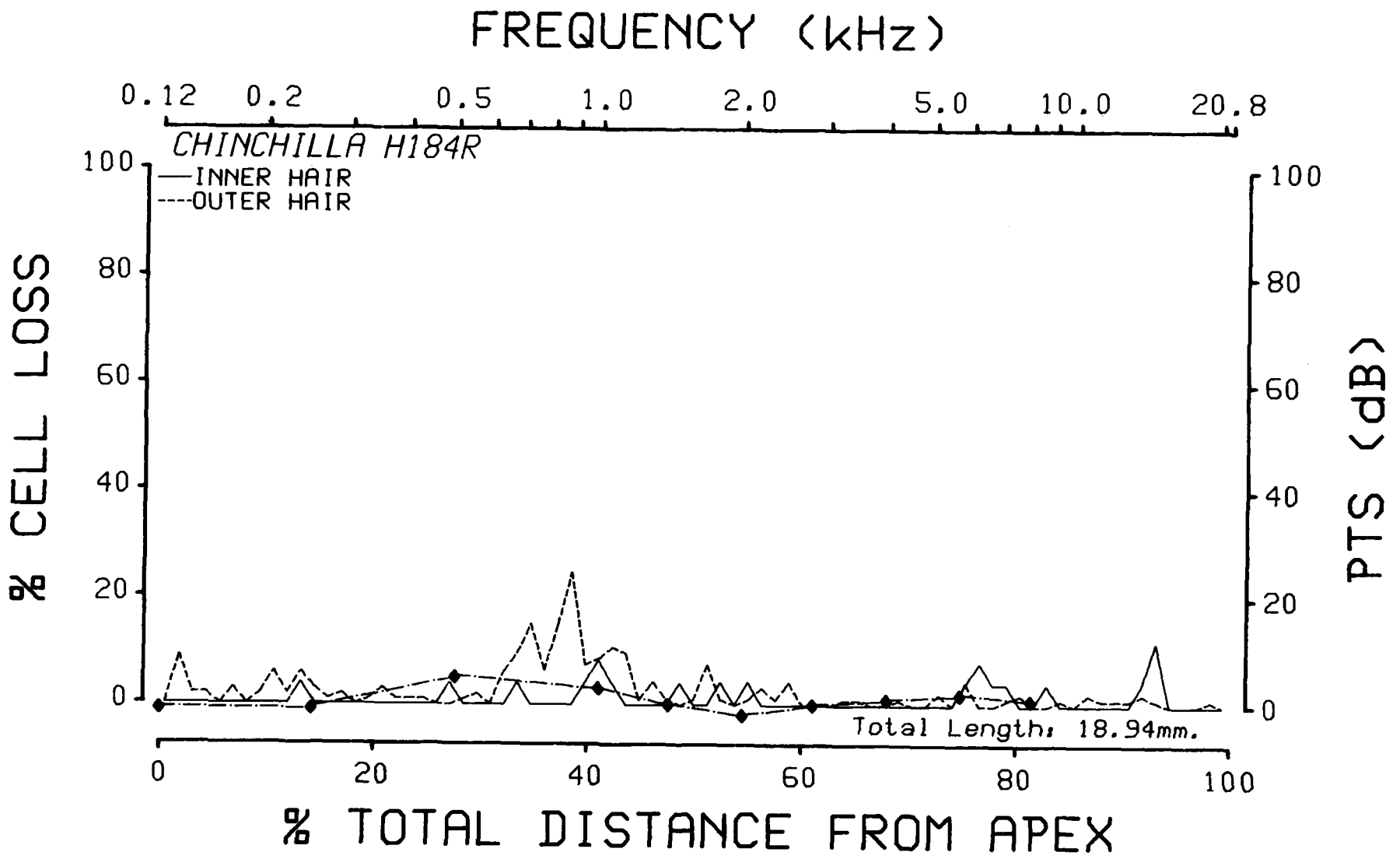
Group 5 - Exposure: 135 dB High peak impulse

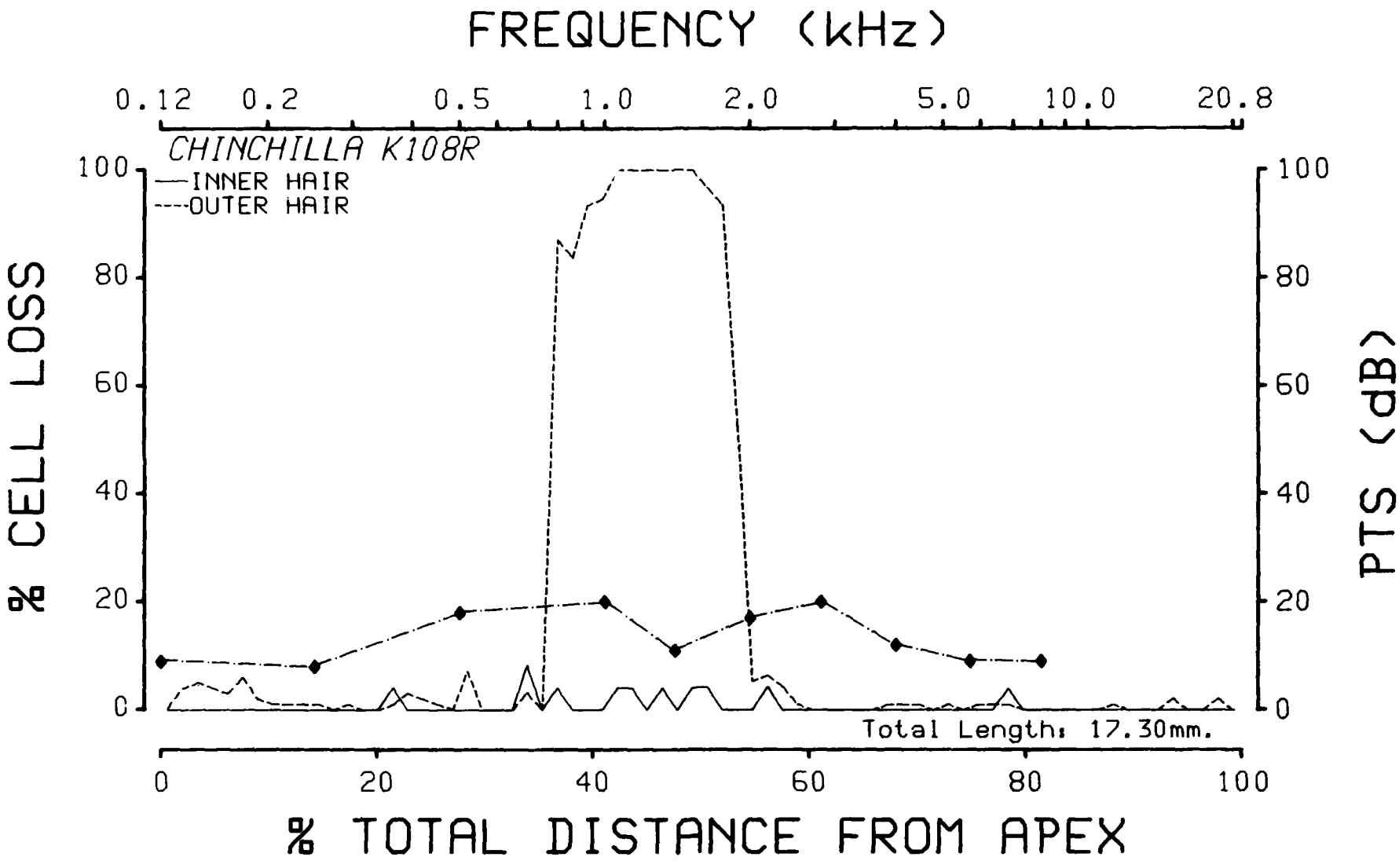
Animals: K68R
K116R
K103R
H184R
K108R
K21R

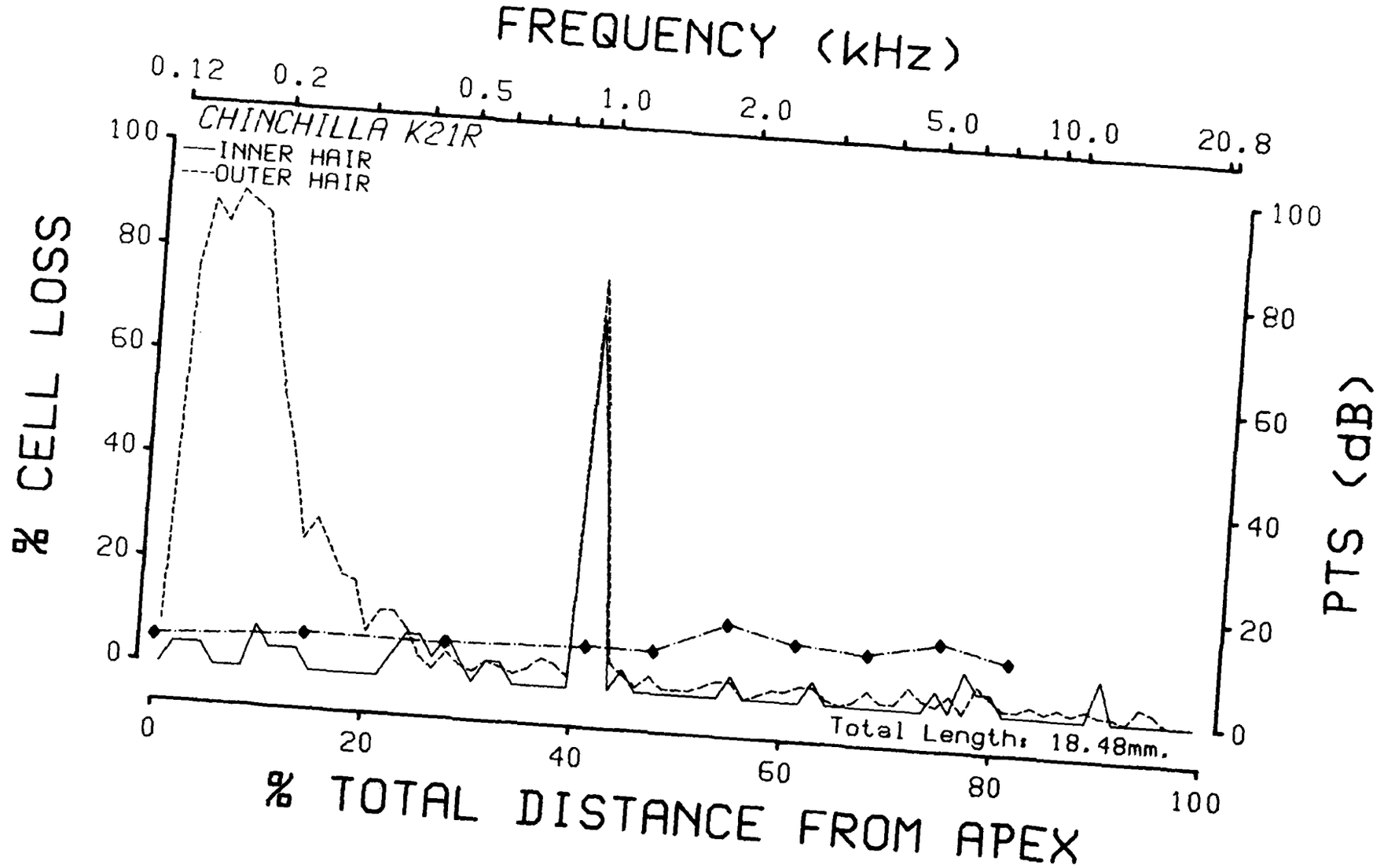

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K68R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
ISO
100
80
60
40
20
0
PTS (dB)
Total Length: 18.88mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K116R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.32mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K103R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.96mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

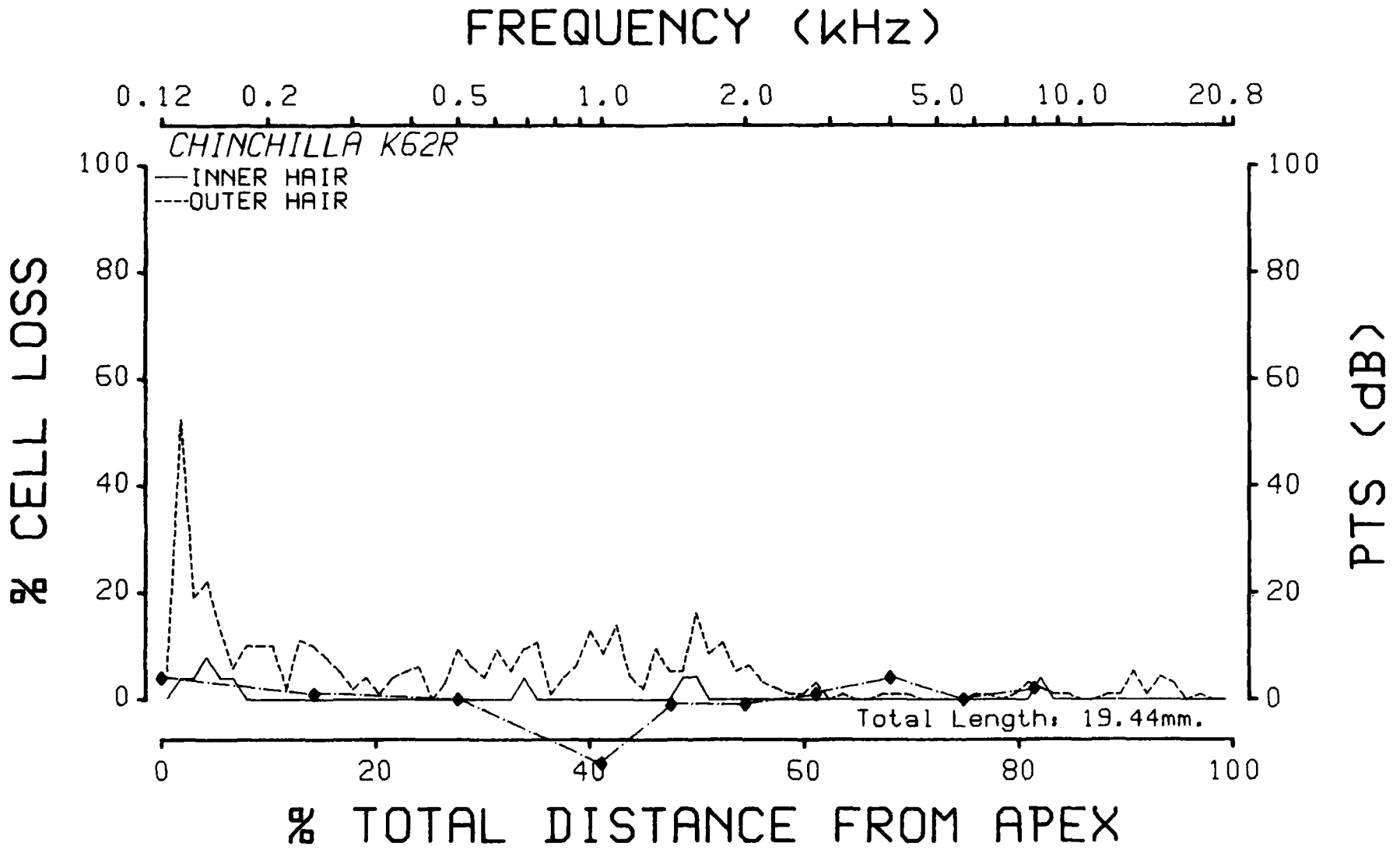

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA H184R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.94mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

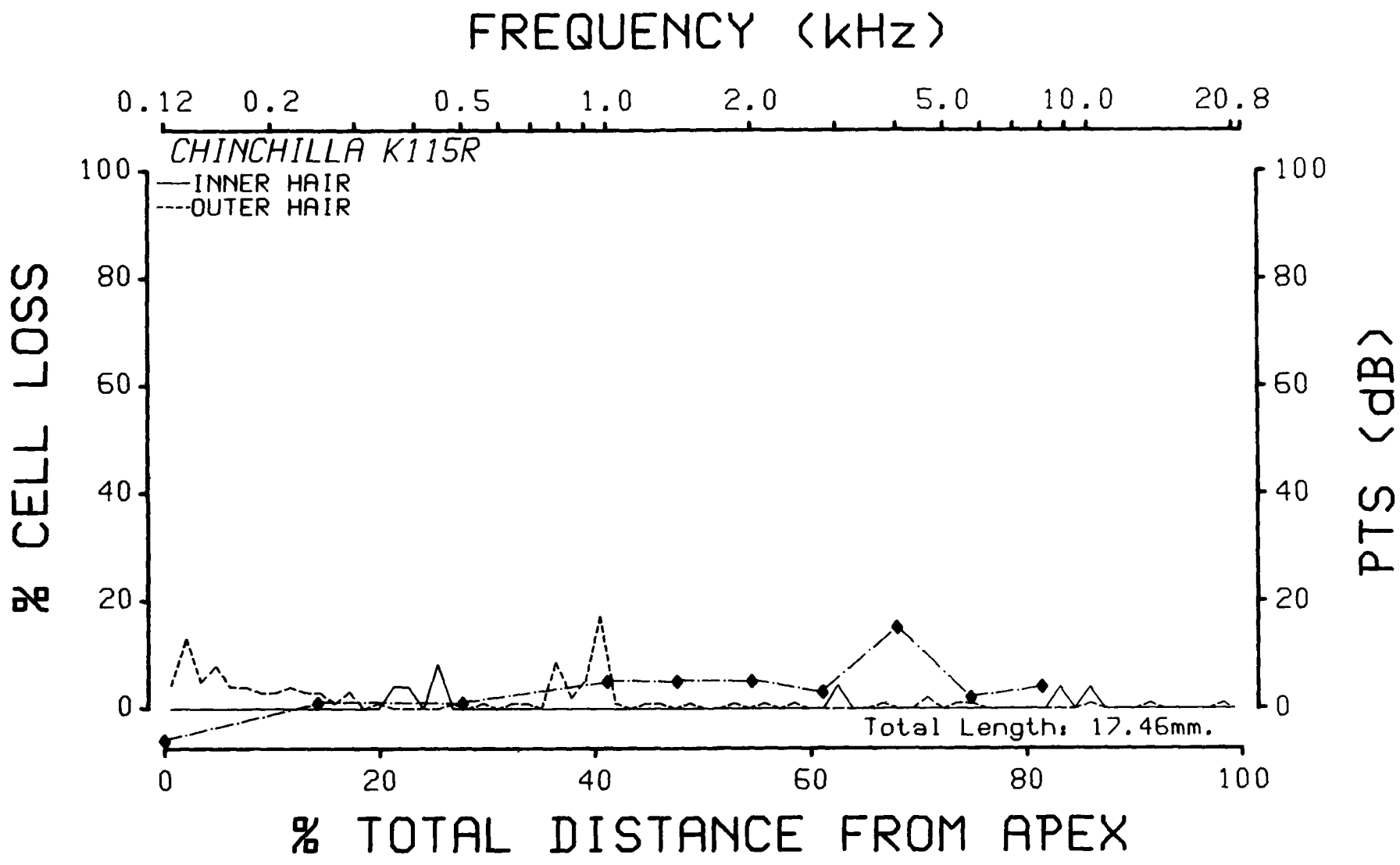

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K108R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 17.30mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

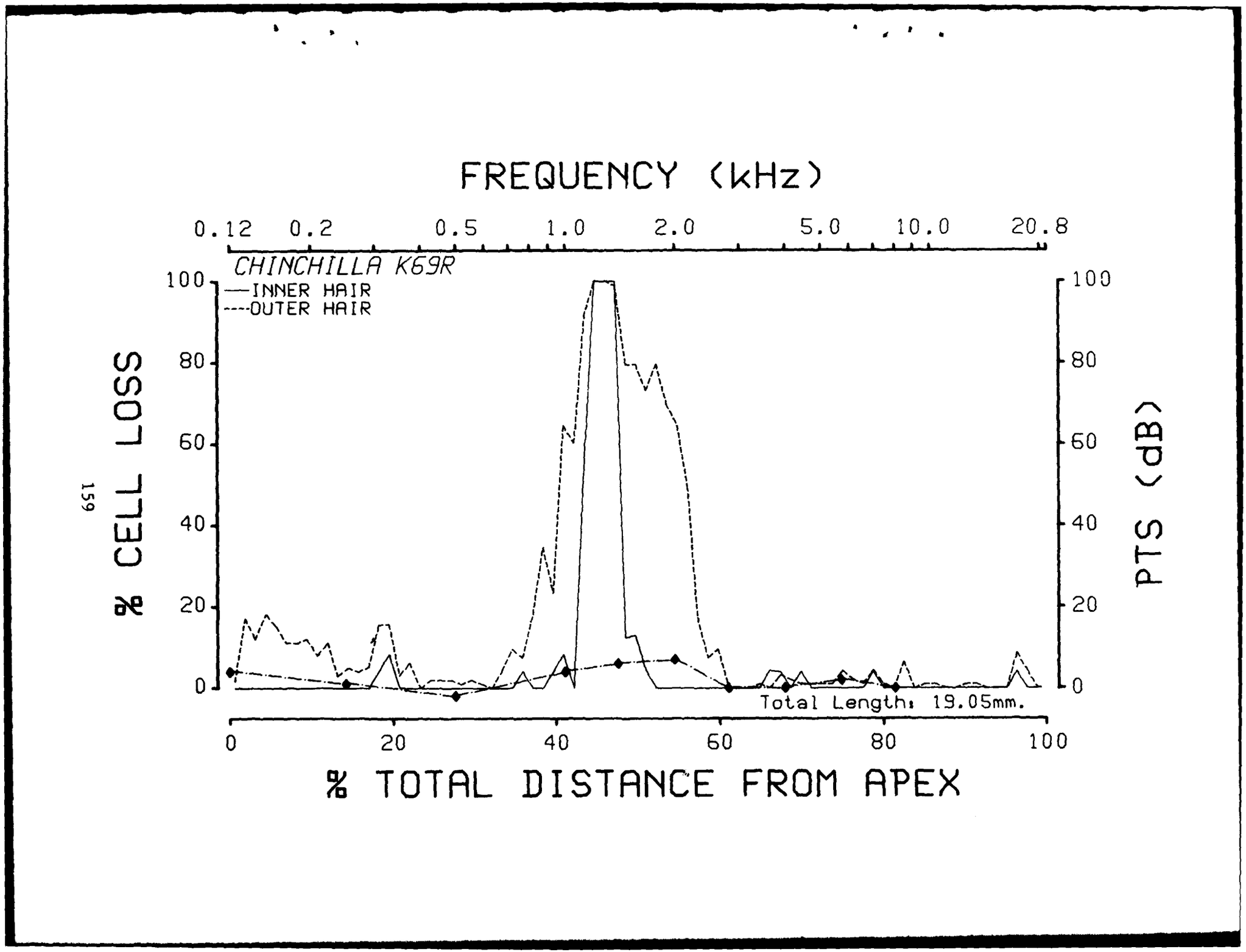

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K21R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 18.48mm.
% TOTAL DISTANCE FROM APEX

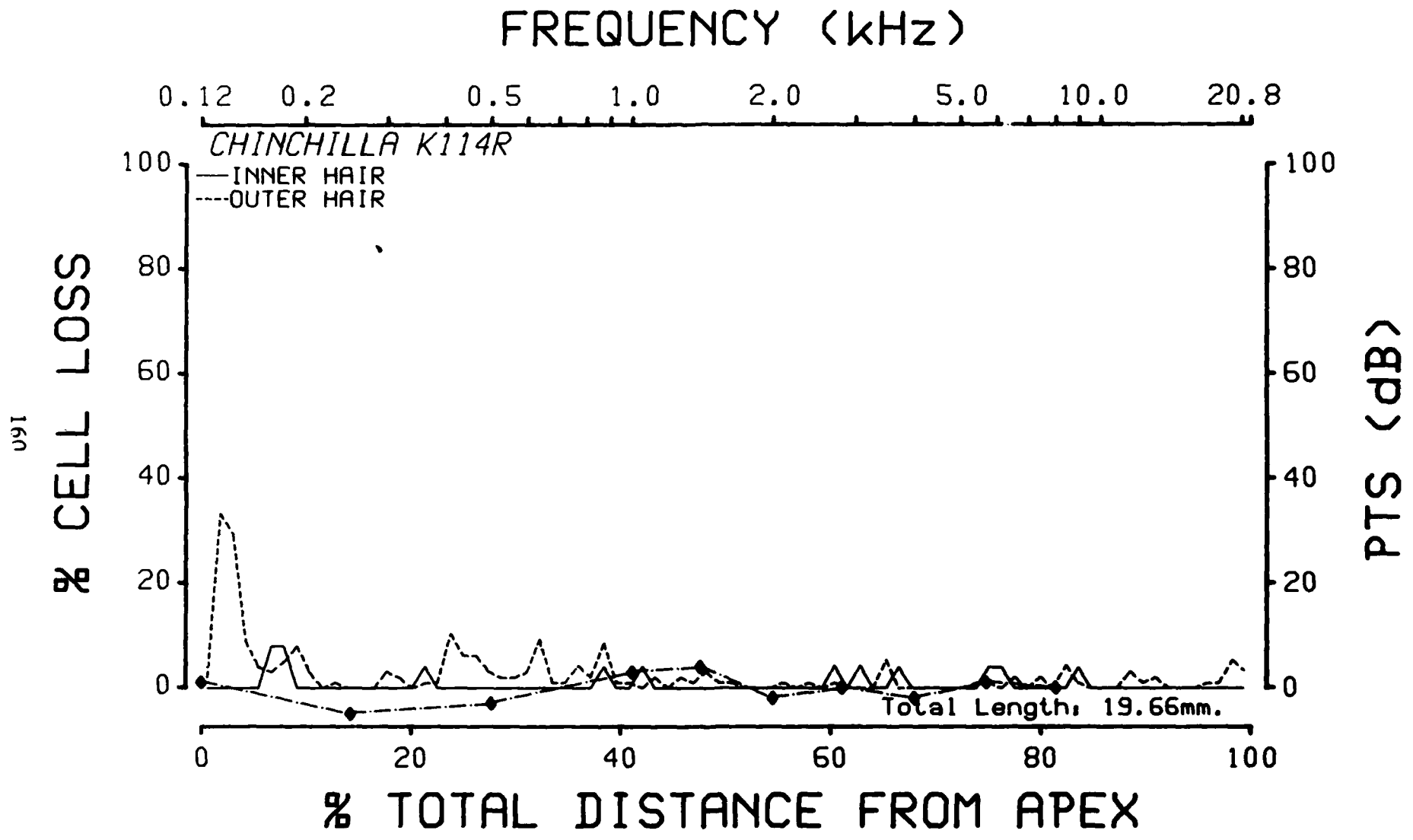
Group 6 - Exposure: 127 dB Low peak impulse

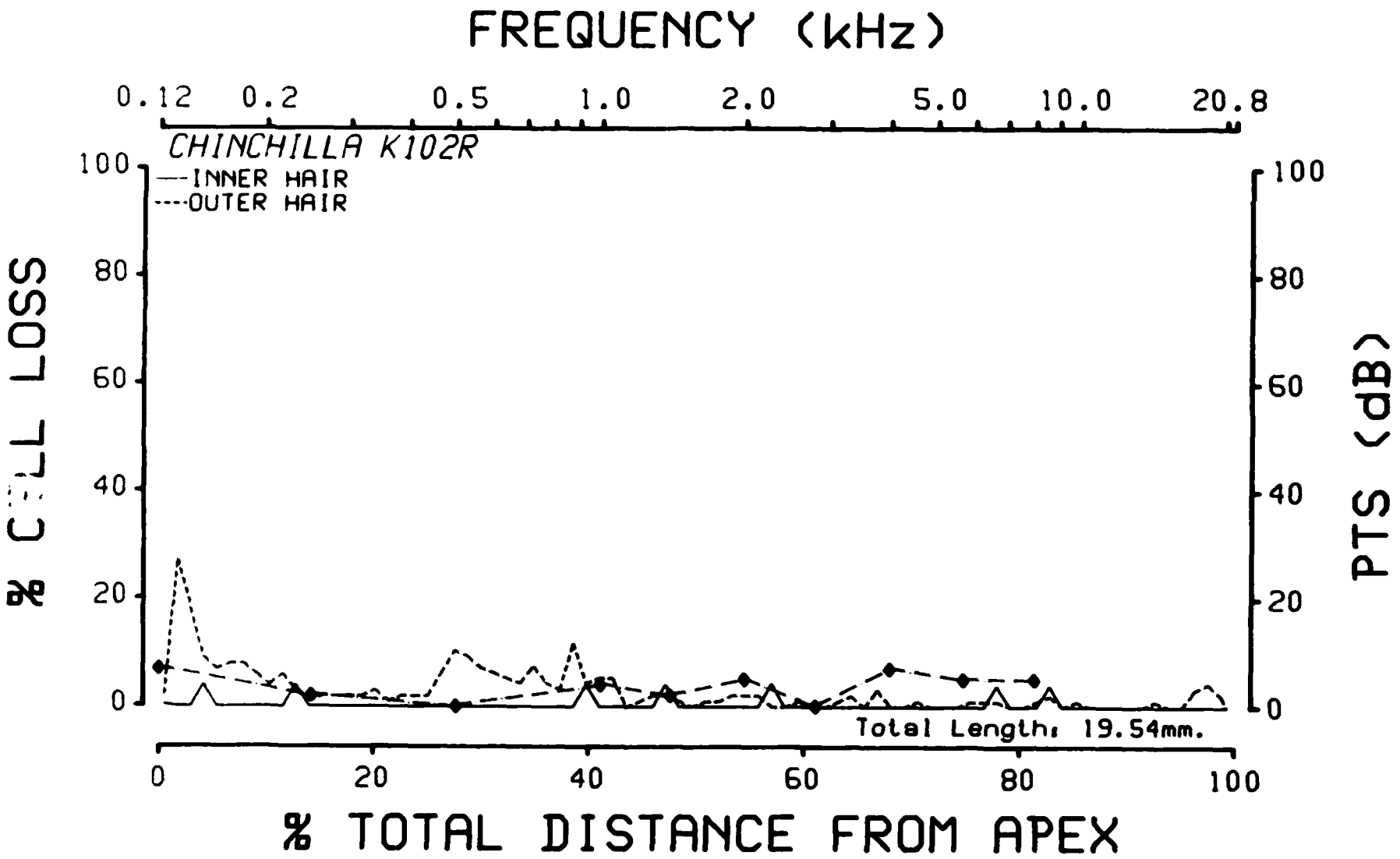
Animals: K62R
K115R
K69R
K114R
K102R
K93R

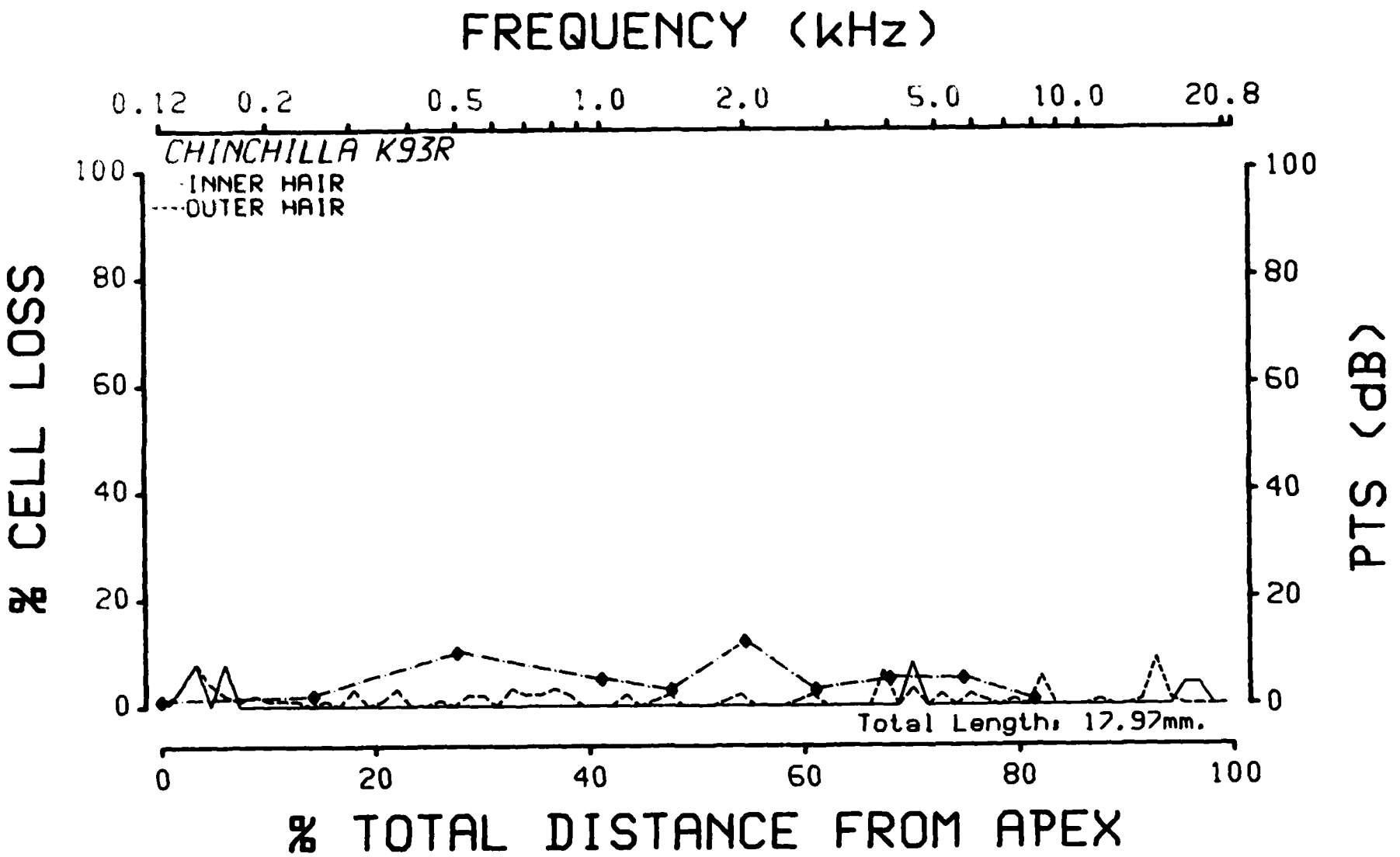

FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K62R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.44mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K115R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 17.46mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K69R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.05mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K114R
—INNER HAIR
----OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.66mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K102R
—INNER HAIR
---OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 19.54mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX


FREQUENCY (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.0
20.8
CHINCHILLA K93R
INNER HAIR
OUTER HAIR
% CELL LOSS
PTS (dB)
100
80
60
40
20
0
Total Length: 17.97mm.
0
20
40
60
80
100
% TOTAL DISTANCE FROM APEX

APPENDIX D

Summary of all the individual and group histological data presented in numerical form as raw data and averaged data. These summary figures were otained from the detailed data that are plotted in Appendix C.

Baseline normal sensory cell densities at various locations of the cochlea. These figures were used to compute the percent loss data.

Total numbers of missing inner and outer sensory cells in each cochlea, as well as average losses across each exposure group.

Percentage of sensory cell losses in octave band lengths of the cochlea tabulated for individual animals and for exposure groups 1 through 6.

THE MEAN NUMBER OF INNER & OUTER HAIR CELLS IN A 0.24mm. SAMPLING WINDOW OF THE COCHLEA AT THE LOCATIONS INDICATED. THESE FIGURES WERE CALCULATED USING A POPULATION OF 30 NORMAL CHINCHILLAS, AND SERVED AS REFERENCE FIGURES IN THE COMPUTATION OF THE PERCENTAGE OF MISSING SENSORY CELLS.

COCHLAR LOCATION % DISTANCE FROM APEX	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS
0 - 17	25	33	33	33
17 - 33	24	32	32	32
33 - 50	24	31	31	31
50 - 67	23	31	31	31
67 - 83	25	31	31	31
83 - 100	25	31	31	31

GROUP 1: 147 dB - High Peak Impulse

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
E115R	841	1831	1767	1475	5073
F1R	580	1307	1298	1275	3880
E138R	258	2191	2083	2110	6384
G2R	168	1694	1435	1059	4188
G20R	1049	2115	2013	1961	6089
G5R	513	1920	1763	1735	5418
GROUP MEAN	568				5740
SD	336				1130

GROUP 1: 147 dB - High Peak Impulse

GROUP MEANS

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND
LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	10 log $\frac{IHC}{1}$	OUTER HAIR CELLS	10 log $\frac{OHC}{10}$
0.125 kHz	7.5	8.8	71.8	8.6
0.25 kHz	12.7	11.0	250.0	14.0
0.5 kHz	53.2	17.3	574.3	17.6
1 kHz	96.2	19.8	883.0	19.5
2 kHz	102.0	20.1	971.8	19.9
4 kHz	92.3	19.7	955.2	19.8
8 kHz	117.8	20.7	830.5	19.2
16 kHz	85.8	19.3	564.2	17.5

STANDARD DEVIATIONS

	TOTAL INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	10.6	39.1
0.25 kHz	15.1	209.9
0.5 kHz	40.7	267.7
1 kHz	89.1	108.3
2 kHz	81.5	47.8
4 kHz	67.5	52.8
8 kHz	85.0	294.0
16 kHz	87.1	413.2

INDIVIDUAL ANIMAL DATA

GROUP 1: 147 dB - High Peak Impulse

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E115R					
0.125 kHz	9	9	7	20	36
0.25 kHz	8	30	12	13	55
0.5 kHz	72	197	181	37	415
1 kHz	65	305	277	111	693
2 kHz	174	341	341	336	1018
4 kHz	113	310	310	309	929
8 kHz	205	341	341	341	1023
16 kHz	176	279	279	279	837
TOTALS	837	1830	1766	1464	5060
CHINCHILLA F1R					
0.125 kHz	0	14	20	26	60
0.25 kHz	5	1	3	17	21
0.5 kHz	45	74	61	49	184
1 kHz	175	327	302	255	884
2 kHz	109	310	310	310	930
4 kHz	148	310	310	310	930
8 kHz	96	266	275	283	824
16 kHz	2	5	17	25	47
TOTALS	580	1307	1298	1275	3880
CHINCHILLA E138R					
0.125 kHz	5	29	36	61	126
0.25 kHz	4	230	128	137	495
0.5 kHz	7	318	306	285	909
1 kHz	115	310	309	306	925
2 kHz	35	341	341	341	1023
4 kHz	28	341	341	341	1023
8 kHz	50	310	310	310	930
16 kHz	13	279	279	279	837
TOTALS	258	2189	2081	2091	6361

GROUP 1: 147 dB - High Peak Impulse - Individual Animal Data (CONTINUED)

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA G2R					
0.125 kHz	2	34	33	27	94
0.25 kHz	42	272	126	55	453
0.5 kHz	66	267	220	97	584
1 kHz	2	335	326	217	878
2 kHz	32	341	341	322	1004
4 kHz	17	310	309	288	907
8 kHz	2	123	77	50	250
16 kHz	5	9	3	3	15
TOTALS	168	1694	1435	1059	4188
CHINCHILLA G20R					
0.125 kHz	28	3	4	16	23
0.25 kHz	15	120	95	142	357
0.5 kHz	116	314	274	243	831
1 kHz	217	341	343	343	1027
2 kHz	223	311	311	311	933
4 kHz	185	304	308	308	920
8 kHz	138	342	345	339	1026
16 kHz	153	280	273	259	812
TOTALS	1075	2055	1992	1998	6045
CHINCHILLA G5R					
0.125 kHz	1	21	35	36	92
0.25 kHz	2	58	28	33	119
0.5 kHz	13	269	141	113	523
1 kHz	3	309	296	286	891
2 kHz	39	310	310	303	923
4 kHz	63	341	341	340	1022
8 kHz	216	310	310	310	930
16 kHz	166	279	279	279	837
TOTALS	508	1919	1762	1722	5403

GROUP 1: 147 dB - High Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	5.9	14.3
0.25 kHz	6.7	27.2
0.5 kHz	21.7	60.4
1 kHz	41.0	91.8
2 kHz	42.6	99.5
4 kHz	37.6	99.5
8 kHz	45.3	83.7
16 kHz	36.4	67.4
STANDARD DEVIATIONS		
0.125 kHz	8.6	8.4
0.25 kHz	7.4	21.6
0.5 kHz	15.8	26.3
1 kHz	36.7	8.6
2 kHz	35.4	0.7
4 kHz	28.7	1.2
8 kHz	33.6	32.6
16 kHz	37.8	50.5

INDIVIDUAL ANIMAL DATA

GROUP 1: 147 dB - High Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E115R					
0.125 kHz	7.3	5.9	3.6	11.2	6.9
0.25 kHz	2.6	8.9	3.7	3.4	5.3
0.5 kHz	30.4	64.0	58.2	12.0	44.7
1 kHz	33.5	98.6	91.5	43.1	77.7
2 kHz	65.3	99.9	99.9	98.3	99.4
4 kHz	45.6	100.0	100.0	99.8	99.9
8 kHz	79.5	100.0	100.0	100.0	100.0
16 kHz	79.2	99.9	99.9	99.9	99.9
CHINCHILLA F1R					
0.125 kHz	0.0	7.4	11.0	14.6	11.0
0.25 kHz	2.8	0.5	0.7	4.9	2.0
0.5 kHz	20.9	31.8	26.2	17.7	25.2
1 kHz	69.0	95.5	89.3	78.9	87.9
2 kHz	47.8	99.9	99.9	99.9	99.9
4 kHz	59.0	100.0	100.0	100.0	100.0
8 kHz	36.2	78.5	83.8	88.4	83.6
16 kHz	0.5	1.4	2.8	3.3	2.5
CHINCHILLA E138R					
0.125 kHz	3.4	21.4	21.3	37.7	26.8
0.25 kHz	1.5	66.1	38.0	38.4	47.5
0.5 kHz	3.5	99.7	95.9	89.6	95.1
1 kHz	48.4	100.0	99.8	99.3	99.7
2 kHz	11.5	99.9	99.9	99.9	99.9
4 kHz	10.8	100.0	100.0	100.0	100.0
8 kHz	19.9	100.0	100.0	100.0	100.0
16 kHz	4.6	99.9	99.9	99.9	99.9

GROUP 1: 147 dB - High Peak Impulse - Individual Animal Data (CONTINUED)

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA G2R					
0.125 kHz	1.3	21.1	20.1	17.5	19.6
0.25 kHz	17.3	80.7	37.5	14.7	44.3
0.5 kHz	24.9	83.6	69.7	29.2	60.8
1 kHz	0.9	99.0	97.2	69.4	88.5
2 kHz	12.8	100.0	100.0	94.3	98.1
4 kHz	6.5	99.5	98.7	93.0	97.0
8 kHz	0.7	30.3	17.0	8.2	18.5
16 kHz	2.0	3.9	0.8	1.0	1.9
CHINCHILLA G20R					
0.125 kHz	22.6	2.0	2.3	9.4	4.6
0.25 kHz	14.7	48.4	39.9	53.8	47.4
0.5 kHz	45.3	98.8	86.8	73.1	86.2
1 kHz	92.4	99.8	100.0	100.0	99.9
2 kHz	99.9	99.9	99.9	99.9	99.9
4 kHz	79.3	100.0	100.0	100.0	100.0
8 kHz	48.0	100.0	100.0	100.0	100.0
16 kHz	59.0	100.0	100.0	100.0	100.0
CHINCHILLA G5R					
0.125kHz	0.6	12.2	18.8	19.7	16.9
0.25 kHz	0.7	22.9	13.3	13.8	16.7
0.5 kHz	5.2	78.3	40.0	31.7	50.0
1 kHz	1.2	99.6	96.1	93.6	96.4
2 kHz	18.1	100.0	100.0	97.8	99.2
4 kHz	23.9	99.9	99.9	99.6	99.8
8 kHz	87.1	99.9	99.9	99.9	99.9
16 kHz	72.7	100.0	100.0	100.0	100.0

GROUP 2: 139 dB - Low Peak Impulse

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
E17R	275	1930	1914	1973	5817
F12R	525	2046	1909	1968	5923
F24R	350	2539	2410	2387	7336
F120R	218	1686	1576	1344	4606
H32R	498	2019	1907	1822	5748
G16R	68	1401	1400	1266	4067
GROUP MEAN	322				5583
SD	173				1142

GROUP 2: 139 dB - Low Peak Impulse

GROUP MEANS

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND
LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	10 log $\frac{IHC}{1}$	OUTER HAIR CELLS	10 log $\frac{OHC}{10}$
0.125 kHz	12.2	10.9	119.3	10.8
0.25 kHz	28.3	14.5	315.2	15.0
0.5 kHz	28.8	14.6	737.7	18.7
1 kHz	79.7	19.0	931.2	19.7
2 kHz	69.5	18.4	987.0	19.9
4 kHz	24.3	13.9	981.3	19.9
8 kHz	8.2	9.1	872.3	19.4
16 kHz	69.8	18.4	598.5	17.8

STANDARD DEVIATIONS

	TOTAL INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	17.5	64.7
0.25 kHz	55.2	323.8
0.5 kHz	17.9	280.1
1 kHz	53.9	64.3
2 kHz	73.8	47.6
4 kHz	19.1	77.3
8 kHz	5.3	129.4
16 kHz	78.4	434.0

INDIVIDUAL ANIMAL DATA

GROUP 2: 139 dB - Low Peak Impulse

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E17R					
0.125 kHz	1	30	33	65	128
0.25 kHz	5	101	82	126	309
0.5 kHz	10	319	319	311	949
1 kHz	47	279	279	279	837
2 kHz	28	310	310	303	923
4 kHz	16	310	310	296	916
8 kHz	16	310	310	310	930
16 kHz	152	248	248	248	744
TOTALS	275	1929	1913	1960	5802
CHINCHILLA F12R					
0.125 kHz	41	13	28	58	99
0.25 kHz	140	162	30	48	240
0.5 kHz	28	317	300	305	922
1 kHz	56	310	310	310	930
2 kHz	52	310	310	310	930
4 kHz	20	310	310	310	930
8 kHz	7	310	307	310	927
16 kHz	181	310	310	310	930
TOTALS	525	2046	1909	1965	5920
CHINCHILLA F24R					
0.125 kHz	0	113	25	59	197
0.25 kHz	3	351	309	279	939
0.5 kHz	62	351	351	344	1046
1 kHz	113	341	341	341	1023
2 kHz	89	341	341	341	1023
4 kHz	10	372	372	372	1116
8 kHz	11	341	341	341	1023
16 kHz	62	308	309	279	896
TOTALS	350	2538	2409	2376	7323

GROUP 2: 139 dB - Low Peak Impulse - Individual Animal Data (CONTINUED)

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA F120R					
0.125 kHz	3	40	19	21	80
0.25 kHz	20	153	80	38	271
0.5 kHz	27	281	255	128	664
1 kHz	99	310	310	272	892
2 kHz	33	339	340	323	1002
4 kHz	24	309	309	305	923
8 kHz	9	232	239	239	710
16 kHz	3	22	24	18	64
TOTALS	218	1686	1576	1344	4606
CHINCHILLA H32R					
0.125 kHz	27	59	60	66	185
0.25 kHz	0	57	31	19	107
0.5 kHz	17	240	164	104	508
1 kHz	157	340	329	305	974
2 kHz	209	341	341	340	1022
4 kHz	62	341	341	337	1019
8 kHz	0	310	310	310	930
16 kHz	17	310	310	310	930
TOTALS	493	2018	1906	1811	5735
CHINCHILLA G16R					
0.125 kHz	1	3	7	17	27
0.25 kHz	2	7	10	8	25
0.5 kHz	29	130	123	84	337
1 kHz	6	333	319	279	931
2 kHz	6	341	341	340	1022
4 kHz	14	341	340	303	984
8 kHz	6	243	249	222	714
16 kHz	4	3	11	13	27
TOTALS	68	1401	1400	1266	4067

GROUP 2: 139 dB - Low Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	10.2	21.6
0.25 kHz	10.7	32.8
0.5 kHz	11.6	75.4
1 kHz	33.7	97.9
2 kHz	25.0	99.5
4 kHz	9.2	98.9
8 kHz	3.9	87.2
16 kHz	30.3	67.8
STANDARD DEVIATIONS		
0.125 kHz	15.6	10.9
0.25 kHz	20.6	30.4
0.5 kHz	6.6	26.7
1 kHz	20.7	2.3
2 kHz	29.0	0.7
4 kHz	7.3	1.3
8 kHz	3.0	19.8
16 kHz	32.8	48.6

INDIVIDUAL ANIMAL DATA

GROUP 2: 139 dB - Low Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA F120R					
0.125 kHz	3.2	22.6	11.6	11.8	15.3
0.25 kHz	7.7	45.7	24.1	11.0	26.9
0.5 kHz	10.8	89.2	81.2	43.0	71.1
1 kHz	43.0	100.0	100.0	88.7	96.2
2 kHz	10.4	99.4	99.7	95.1	98.1
4 kHz	9.8	99.3	99.6	98.1	99.0
8 kHz	2.6	61.6	63.6	63.7	63.0
16 kHz	1.3	7.5	8.0	6.2	7.2
CHINCHILLA H32R					
0.125 kHz	17.9	29.6	30.2	33.2	31.0
0.25 kHz	0.0	18.2	9.1	6.1	11.1
0.5 kHz	7.3	73.4	51.1	34.2	52.9
1 kHz	64.0	99.7	98.5	90.6	96.3
2 kHz	79.3	100.0	100.0	99.7	99.9
4 kHz	23.1	100.0	100.0	98.8	99.6
8 kHz	0.7	100.0	100.0	100.0	100.0
16 kHz	12.6	100.0	100.0	100.0	100.0
CHINCHILLA G16R					
0.125 kHz	0.7	1.5	3.5	8.5	4.5
0.25 kHz	0.7	2.2	3.4	4.1	3.2
0.5 kHz	10.9	43.9	40.5	23.4	35.9
1 kHz	2.6	99.4	96.5	89.5	95.1
2 kHz	2.0	100.0	100.0	98.9	99.6
4 kHz	5.5	100.0	99.7	89.8	96.5
8 kHz	1.8	61.6	63.4	55.5	60.2
16 kHz	1.6	1.0	3.5	4.2	2.9

GROUP 2: 139 dB - Low Peak Impulse - Individual Animal Data (CONTINUED)

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E17R					
0.125 kHz	0.7	18.2	19.1	38.4	25.2
0.25 kHz	2.2	41.3	35.6	48.2	41.7
0.5 kHz	6.9	100.0	100.0	98.3	99.4
1 kHz	24.1	100.0	100.0	100.0	100.0
2 kHz	6.5	100.0	100.0	97.7	99.2
4 kHz	6.7	100.0	100.0	95.4	98.5
8 kHz	9.1	100.0	100.0	100.0	100.0
16 kHz	67.0	100.0	100.0	100.0	100.0
CHINCHILLA F12R					
0.125 kHz	38.9	10.0	15.6	33.0	19.5
0.25 kHz	52.4	51.9	10.1	13.7	25.2
0.5 kHz	8.8	93.9	92.2	94.5	93.5
1 kHz	27.7	100.0	100.0	100.0	100.0
2 kHz	16.6	100.0	100.0	100.0	100.0
4 kHz	7.8	100.0	100.0	100.0	100.0
8 kHz	5.0	100.0	99.1	100.0	99.7
16 kHz	75.1	100.0	100.0	100.0	100.0
CHINCHILLA F24R					
0.125 kHz	0.0	58.7	13.7	29.9	34.1
0.25 kHz	1.1	97.9	87.8	79.6	88.4
0.5 kHz	24.6	100.0	100.0	98.1	99.4
1 kHz	40.8	100.0	100.0	100.0	100.0
2 kHz	35.2	100.0	100.0	100.0	100.0
4 kHz	2.2	100.0	100.0	100.0	100.0
8 kHz	3.9	100.0	100.0	100.0	100.0
16 kHz	24.4	99.4	99.7	90.2	96.4

GROUP 3: 139 dB - High Peak Impulse

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
E109R	95	445	482	439	1366
G30R	240	1160	1147	1099	3406
E144R	38	839	708	520	2067
H16R	23	876	930	658	2464
H1R	83	523	440	498	1461
H42R	109	836	780	763	2379
GROUP MEAN	98				2191
SD	77				750

GROUP 3: 139 dB - High Peak Impulse

GROUP MEANS

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND
LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	10 log $\frac{IHC}{1}$	OUTER HAIR CELLS	10 log $\frac{OHC}{10}$
0.125 kHz	1.7	2.3	118.7	10.7
0.25 kHz	3.2	5.1	60.3	7.8
0.5 kHz	4.0	6.0	348.5	15.4
1 kHz	41.7	16.2	689.2	18.4
2 kHz	27.8	14.4	607.8	17.8
4 kHz	10.3	10.1	191.3	12.8
8 kHz	8.5	9.3	63.3	8.0
16 kHz	1.0	0	26.8	4.3

STANDARD DEVIATIONS

	TOTAL INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	2.3	106.4
0.25 kHz	1.7	27.7
0.5 kHz	2.6	233.0
1 kHz	40.7	338.2
2 kHz	33.7	363.3
4 kHz	13.7	179.0
8 kHz	11.4	85.6
16 kHz	1.5	51.3

INDIVIDUAL ANIMAL DATA

GROUP 3: 139 dB - High Peak Impulse

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E109R					
0.125 kHz	0	3	15	42	60
0.25 kHz	6	4	12	48	64
0.5 kHz	2	142	134	93	369
1 kHz	72	268	263	222	753
2 kHz	3	6	34	10	50
4 kHz	4	4	3	6	13
8 kHz	8	18	20	17	55
16 kHz	0	0	1	1	2
TOTALS	95	445	482	439	1366
CHINCHILLA G30R					
0. 125 kHz	5	34	62	64	160
0.25 kHz	1	36	19	33	88
0.5 kHz	6	245	207	181	633
1 kHz	107	340	340	332	1012
2 kHz	84	341	341	318	1000
4 kHz	37	163	178	168	509
8 kHz	0	2	1	3	6
16 kHz	1	0	0	1	1
TOTALS	241	1161	1148	1100	3409
CHINCHILLA E144R					
0.125 kHz	0	5	14	35	54
0.25 kHz	4	10	4	28	42
0.5 kHz	0	113	67	42	222
1 kHz	0	298	233	101	632
2 kHz	0	254	241	45	540
4 kHz	3	77	69	65	211
8 kHz	31	59	52	124	235
16 kHz	0	23	28	80	131
TOTALS	38	839	708	520	2067

GROUP 3: 139 dB High Peak Impulse - Individual Animal Data (CONTINUED)

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H16R					
0.125 kHz	1	100	121	98	319
0.25 kHz	2	17	10	65	92
0.5 kHz	7	259	217	132	608
1 kHz	8	310	309	269	888
2 kHz	2	170	242	55	467
4 kHz	2	14	16	18	48
8 kHz	1	2	12	13	27
16 kHz	0	4	3	8	15
TOTALS	23	876	930	658	2464
CHINCHILLA H1R					
0.125 kHz	4	11	19	22	52
0.25 kHz	3	18	17	22	57
0.5 kHz	5	32	12	12	56
1 kHz	30	264	193	103	560
2 kHz	29	188	188	195	571
4 kHz	3	4	6	117	127
8 kHz	5	5	3	26	34
16 kHz	4	1	2	1	4
TOTALS	83	523	440	498	1461
CHINCHILLA H42R					
0.125 kHz	0	15	32	20	67
0.25 kHz	3	2	7	10	19
0.5 kHz	4	59	44	100	203
1 kHz	33	310	252	238	800
2 kHz	49	341	341	337	1019
4 kHz	13	96	94	50	240
8 kHz	6	10	6	7	23
16 kHz	1	3	4	1	8
TOTALS	109	836	780	763	2379

GROUP 3: 139 dB - High Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	1.5	21.6
0.25 kHz	1.2	5.9
0.5 kHz	1.6	35.9
1 kHz	16.0	80.8
2 kHz	11.5	60.5
4 kHz	4.4	18.4
8 kHz	3.2	7.0
16 kHz	0.4	2.3
STANDARD DEVIATIONS		
0.125 kHz	1.5	19.4
0.25 kHz	1.2	2.9
0.5 kHz	1.6	23.3
1 kHz	14.9	15.1
2 kHz	14.0	35.6
4 kHz	6.9	20.8
8 kHz	4.4	10.6
16 kHz	0.4	3.9

INDIVIDUAL ANIMAL DATA

GROUP 3: 139 dB - High Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA E109R					
0.125 kHz	0.3	1.6	8.8	25.9	12.1
0.25 kHz	2.2	1.2	3.6	13.9	6.2
0.5 kHz	1.0	47.6	44.9	31.5	41.3
1 kHz	30.4	85.3	84.0	70.3	79.9
2 kHz	1.3	1.9	10.6	3.1	5.2
4 kHz	1.7	1.5	1.2	2.2	1.7
8 kHz	3.0	5.5	6.1	5.1	5.6
16 kHz	0.0	0.0	0.3	0.3	0.2
CHINCHILLA G30R					
0.125 kHz	3.3	17.5	31.6	32.4	27.2
0.25 kHz	0.6	10.8	5.6	9.8	8.7
0.5 kHz	2.0	71.6	60.6	53.0	61.7
1 kHz	37.3	99.6	99.6	97.2	98.8
2 kHz	35.0	100.0	100.0	95.7	98.5
4 kHz	18.3	57.5	62.1	56.4	58.6
8 kHz	0.0	0.6	0.3	0.6	0.5
16 kHz	0.4	0.0	0.0	0.6	0.2
CHINCHILLA E144R					
0.125 kHz	1.0	2.6	7.7	20.8	10.4
0.25 kHz	1.0	3.2	1.5	7.0	3.9
0.5 kHz	0.0	36.0	20.3	13.0	23.1
1 kHz	0.0	96.7	77.2	32.3	68.8
2 kHz	0.0	82.9	79.3	21.8	61.3
4 kHz	1.1	15.2	12.8	12.1	13.4
8 kHz	11.9	21.9	20.5	42.7	28.4
16 kHz	0.0	3.9	4.6	22.2	10.2

GROUP 3: 139 dB - High Peak Impulse - Individual Animal Data (CONTINUED)

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H16R					
0.125 kHz	0.6	54.7	65.0	56.8	58.8
0.25 kHz	1.1	8.0	2.6	17.7	9.4
0.5 kHz	2.4	77.3	68.3	41.7	62.4
1 kHz	3.2	100.0	99.6	86.4	95.3
2 kHz	0.8	47.9	70.8	13.5	44.1
4 kHz	0.8	4.3	4.6	5.0	4.6
8 kHz	0.3	0.6	3.6	4.0	2.7
16 kHz	0.0	1.3	0.8	2.7	1.6
CHINCHILLA H1R					
0.125 kHz	3.3	6.5	10.5	12.5	9.9
0.25 kHz	0.7	4.7	4.4	5.5	4.9
0.5 kHz	2.4	9.3	3.4	3.4	5.4
1 kHz	11.5	82.7	61.6	34.3	59.5
2 kHz	11.3	51.9	51.9	59.2	54.3
4 kHz	1.0	1.4	1.6	31.7	11.5
8 kHz	1.5	1.1	0.8	5.2	2.4
16 kHz	1.6	0.3	0.6	0.3	0.4
CHINCHILLA H42R					
0.125 kHz	0.0	7.5	16.0	10.0	11.2
0.25 kHz	1.1	0.5	2.0	3.3	1.9
0.5 kHz	1.5	19.6	14.1	29.0	20.9
1 kHz	13.3	94.3	78.1	74.5	82.3
2 kHz	20.4	99.9	99.9	98.8	99.6
4 kHz	3.5	25.2	24.6	11.6	20.5
8 kHz	2.1	2.9	1.7	2.0	2.2
16 kHz	0.4	0.9	1.3	0.3	0.8

GROUP 4: 131 dB - Low Peak Impulse

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
D22R	141	558	441	388	1387
F113R	133	968	915	619	2502
F2R	92	192	214	260	666
H12R	62	765	730	608	2103
H2R	35	527	512	356	1395
G9R	43	143	129	199	471
GROUP MEAN	84				1421
SD	45				788

GROUP 4: 131 dB - Low Peak Impulse

GROUP MEANS

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND
LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	10 log $\frac{IHC}{1}$	OUTER HAIR CELLS	10 log $\frac{OHC}{10}$
0.125 kHz	3.5	5.4	75.2	8.8
0.25 kHz	10.0	10.0	161.8	12.1
0.5 kHz	4.0	6.0	229.3	13.6
1 kHz	44.8	16.5	619.3	17.9
2 kHz	10.8	10.3	254.3	14.1
4 kHz	0.7	-1.5	11.0	0.4
8 kHz	2.8	4.5	33.3	5.4
16 kHz	7.8	8.9	20.3	3.1

STANDARD DEVIATIONS

	TOTAL INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	4.7	52.4
0.25 kHz	16.9	188.3
0.5 kHz	7.4	191.3
1 kHz	32.1	271.9
2 kHz	17.5	309.3
4 kHz	0.8	5.6
8 kHz	4.1	39.1
16 kHz	18.7	37.2

INDIVIDUAL ANIMAL DATA

GROUP 4: 131 dB - Low Peak Impulse

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA D22R					
0.125 kHz	6	11	22	46	79
0.25 kHz	44	188	160	155	503
0.5 kHz	2	160	60	26	264
1 kHz	85	169	171	123	463
2 kHz	3	16	16	17	49
4 kHz	0	8	3	8	19
8 kHz	1	5	5	9	19
16 kHz	0	1	4	4	9
TOTALS	141	558	441	388	1387
CHINCHILLA F113R					
0.125 kHz	1	9	24	41	74
0.25 kHz	5	130	68	63	261
0.5 kHz	2	266	222	61	549
1 kHz	50	309	307	253	869
2 kHz	17	190	206	145	541
4 kHz	1	0	8	2	10
8 kHz	11	31	45	24	100
16 kHz	46	32	34	30	96
TOTALS	133	968	915	619	2505
CHINCHILLA F2R					
0.125 kHz	12	21	34	41	96
0.25 kHz	2	6	2	45	53
0.5 kHz	1	8	4	18	30
1 kHz	74	127	122	117	366
2 kHz	1	2	2	1	5
4 kHz	0	3	1	3	7
8 kHz	2	3	1	2	6
16 kHz	0	0	1	6	7
TOTALS	92	192	191	260	643

GROUP 4: 131 dB - Low Peak Impulse - Individual Animal Data (CONTINUED)

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H12R					
0.125 kHz	1	50	68	41	159
0.25 kHz	0	3	2	17	22
0.5 kHz	0	112	76	72	260
1 kHz	15	341	325	237	903
2 kHz	44	251	252	232	735
4 kHz	1	7	6	4	17
8 kHz	1	0	1	4	5
16 kHz	0	1	0	1	2
TOTALS	62	765	730	608	2103
CHINCHILLA H2R					
0.125 kHz	0	6	15	16	37
0.25 kHz	8	5	12	23	40
0.5 kHz	19	96	87	76	259
1 kHz	3	310	310	193	813
2 kHz	0	78	66	31	175
4 kHz	2	4	2	1	7
8 kHz	2	27	19	16	62
16 kHz	1	1	1	0	2
TOTALS	35	527	512	356	1395
CHINCHILLA G9R					
0.125 kHz	1	0	4	2	6
0.25 kHz	1	45	12	35	92
0.5 kHz	0	3	17	12	32
1 kHz	42	81	89	132	302
2 kHz	0	6	1	14	21
4 kHz	0	3	2	1	6
8 kHz	0	5	1	2	8
16 kHz	0	0	3	3	6
TOTALS	44	143	129	201	473

GROUP 4: 131 dB - Low Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	2.5	13.4
0.25 kHz	3.8	15.8
0.5 kHz	1.7	24.5
1 kHz	17.9	63.4
2 kHz	4.1	22.0
4 kHz	0.3	1.0
8 kHz	1.1	3.5
16 kHz	3.3	3.3
STANDARD DEVIATIONS		
0.125 kHz	3.4	8.3
0.25 kHz	6.4	18.8
0.5 kHz	2.8	19.4
1 kHz	12.6	28.2
2 kHz	6.5	27.4
4 kHz	0.3	0.4
8 kHz	1.5	3.9
16 kHz	7.8	4.7

INDIVIDUAL ANIMAL DATA

GROUP 4: 131 dB - Low Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H12R					
0.125 kHz	0.6	24.2	33.1	20.6	26.0
0.25 kHz	0.0	0.8	0.5	4.4	1.9
0.5 kHz	0.5	37.4	26.8	24.9	29.7
1 kHz	5.7	100.0	96.0	70.8	88.9
2 kHz	16.2	64.2	64.4	59.0	62.6
4 kHz	0.5	1.9	1.7	1.1	1.6
8 kHz	0.2	0.0	0.3	1.1	0.5
16 kHz	0.0	0.3	0.0	0.3	0.2
CHINCHILLA H2R					
0.125 kHz	0.0	3.2	9.1	11.4	7.9
0.25 kHz	3.5	1.7	3.7	5.6	3.7
0.5 kHz	7.4	38.5	35.4	32.5	35.5
1 kHz	1.2	99.9	98.5	52.6	83.6
2 kHz	0.0	14.7	12.2	9.4	12.1
4 kHz	0.8	1.3	0.6	0.3	0.7
8 kHz	0.8	8.7	6.0	5.0	6.6
16 kHz	0.4	0.1	0.4	0.0	0.1
CHINCHILLA G9R					
0.125 kHz	0.7	1.8	2.2	1.1	1.7
0.25 kHz	0.4	12.5	3.8	10.7	9.0
0.5 kHz	0.0	0.9	5.6	3.8	3.5
1 kHz	18.1	25.3	26.9	40.0	30.7
2 kHz	0.0	1.3	0.3	3.6	1.7
4 kHz	0.0	1.0	0.6	0.4	0.7
8 kHz	0.0	1.4	0.9	1.4	1.3
16 kHz	0.0	0.0	0.3	0.0	0.1

GROUP 4: 131 dB - Low Peak Impulse - Individual Animal Data (CONTINUED)

% SENSORY CELL LOSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA D22R					
0.125 kHz	4.0	5.6	11.1	23.2	13.3
0.25 kHz	16.5	59.7	45.6	44.5	49.9
0.5 kHz	1.3	41.2	18.2	7.2	22.2
1 kHz	32.8	49.9	50.7	37.5	46.1
2 kHz	0.9	4.5	4.4	4.3	4.4
4 kHz	0.0	2.2	0.8	2.3	1.7
8 kHz	0.4	1.5	1.5	2.7	1.9
16 kHz	0.0	0.3	1.3	1.3	1.0
CHINCHILLA F113R					
0.125 kHz	0.7	4.6	14.2	22.9	13.9
0.25 kHz	1.9	40.1	19.4	17.7	25.7
0.5 kHz	0.8	76.2	65.0	17.8	53.0
1 kHz	19.9	99.7	98.9	80.8	93.1
2 kHz	6.9	53.2	58.3	41.3	50.9
4 kHz	0.4	0.0	2.6	0.6	1.1
8 kHz	4.1	9.4	13.4	7.3	10.0
16 kHz	19.3	11.1	11.8	10.1	11.0
CHINCHILLA F2R					
0.125 kHz	8.8	11.7	18.0	22.5	17.4
0.25 kHz	0.4	1.2	0.4	12.4	4.7
0.5 kHz	0.4	2.4	1.1	5.3	2.9
1 kHz	29.5	39.2	37.7	36.1	37.7
2 kHz	0.4	0.6	0.6	0.3	0.5
4 kHz	0.0	1.4	0.5	0.9	0.9
8 kHz	0.8	0.4	0.1	0.6	0.4
16 kHz	0.0	7.0	8.0	7.7	7.5

GROUP 5: 135 dB - High Peak Impulse

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
H184R	20	57	75	71	203
K21R	56	270	326	539	1135
K108R	11	410	415	371	1196
K103R	187	515	604	419	1538
K68R	80	214	252	320	786
K116R	9	27	24	77	128
GROUP MEAN	61				831
SD	68				569

GROUP 5: 135 dB - High Peak Impulse

GROUP MEANS

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND
LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	10 log $\frac{IHC}{1}$	OUTER HAIR CELLS	10 log $\frac{OHC}{10}$
0.125 kHz	1.2	0.8	126.0	11.0
0.25 kHz	1.2	0.8	133.8	11.3
0.5 kHz	3.2	5.1	35.2	5.5
1 kHz	49.3	16.9	357.3	15.5
2 kHz	1.2	0.8	144.3	11.6
4 kHz	0.8	-0.9	9.8	-0.1
8 kHz	2.2	3.4	12.0	0.8
16 kHz	1.2	0.8	11.0	0.4

STANDARD DEVIATIONS

	TOTAL INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	1.5	155.9
0.25 kHz	1.9	167.7
0.5 kHz	3.9	24.2
1 kHz	70.1	344.4
2 kHz	1.5	203.6
4 kHz	0.8	6.7
8 kHz	2.6	7.2
16 kHz	1.6	9.1

INDIVIDUAL ANIMAL DATA

GROUP 5: 135 dB - High Peak Impulse

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H184R					
0.125 kHz	0	2	2	12	16
0.25 kHz	1	6	8	12	26
0.5 kHz	1	3	3	9	15
1 kHz	5	35	45	25	105
2 kHz	3	4	9	6	19
4 kHz	0	3	0	2	5
8 kHz	6	1	5	4	10
16 kHz	4	3	3	1	7
TOTALS	20	57	75	71	203
CHINCHILLA K21R					
0.125 kHz	3	125	147	147	419
0.25 kHz	5	78	115	253	446
0.5 kHz	11	4	1	59	64
1 kHz	28	44	45	50	139
2 kHz	1	8	7	2	17
4 kHz	1	4	7	10	21
8 kHz	5	4	1	14	19
16 kHz	2	3	3	4	10
TOTALS	56	270	326	539	1135
CHINCHILLA K108R					
0.125 kHz	0	0	3	17	20
0.25 kHz	0	0	1	12	13
0.5 kHz	1	4	5	5	14
1 kHz	6	244	246	219	709
2 kHz	3	156	156	116	428
4 kHz	0	2	1	1	4
8 kHz	1	0	3	0	3
16 kHz	0	4	0	1	5
TOTALS	11	410	415	371	1196

GROUP 5: 135 dB - High Peak Impulse - Individual Animal Data (CONTINUED)

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K103R					
0.125 kHz	1	7	32	56	95
0.25 kHz	1	15	13	49	77
0.5 kHz	1	28	22	16	66
1 kHz	180	295	297	251	843
2 kHz	0	155	202	28	385
4 kHz	2	2	9	3	14
8 kHz	0	4	13	5	22
16 kHz	0	5	12	11	28
TOTALS	187	515	604	419	1538
CHINCHILLA K68R					
0.125 kHz	0	83	57	35	175
0.25 kHz	0	2	70	130	202
0.5 kHz	2	6	4	24	34
1 kHz	77	113	113	114	340
2 kHz	0	5	1	5	11
4 kHz	1	3	3	4	10
8 kHz	0	1	4	6	11
16 kHz	0	1	0	2	3
TOTALS	80	214	252	320	786
CHINCHILLA K116R					
0.125 kHz	3	5	9	17	31
0.25 kHz	0	3	2	34	39
0.5 kHz	3	3	5	10	18
1 kHz	0	2	1	5	8
2 kHz	0	3	2	1	6
4 kHz	1	1	1	3	5
8 kHz	1	5	2	0	7
16 kHz	1	4	2	7	13
TOTALS	9	27	24	77	128

GROUP 5: 135 dB - High Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	0.8	25.2
0.25 kHz	0.5	11.6
0.5 kHz	1.5	3.5
1 kHz	19.6	39.3
2 kHz	0.5	13.6
4 kHz	0.4	1.1
8 kHz	0.7	1.2
16 kHz	0.6	1.4
STANDARD DEVIATIONS		
0.125 kHz	1.0	31.8
0.25 kHz	0.8	14.4
0.5 kHz	1.5	2.1
1 kHz	28.1	39.0
2 kHz	0.6	19.1
4 kHz	0.3	0.6
8 kHz	1.0	0.7
16 kHz	0.6	1.3

INDIVIDUAL ANIMAL DATA

GROUP 5: 135 dB - High Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA H184R					
0.125 kHz	0.0	1.4	1.9	6.1	3.2
0.25 kHz	0.3	1.5	1.8	3.6	2.3
0.5 kHz	0.7	2.2	2.0	2.4	2.2
1 kHz	1.5	9.2	12.7	7.7	9.9
2 kHz	1.2	1.2	2.5	1.8	1.8
4 kHz	0.0	0.9	0.0	0.6	0.5
8 kHz	1.2	0.3	1.6	1.2	1.0
16 kHz	1.6	1.0	0.8	0.3	0.7
CHINCHILLA K21R					
0.125 kHz	2.0	77.3	88.5	89.7	85.1
0.25 kHz	1.9	17.1	28.0	70.9	38.7
0.5 kHz	4.4	1.1	0.3	15.8	5.7
1 kHz	11.4	13.7	14.7	15.8	14.7
2 kHz	0.4	2.4	1.9	0.8	1.7
4 kHz	0.5	1.2	1.8	2.9	2.0
8 kHz	1.8	1.2	0.5	4.2	2.0
16 kHz	0.8	1.0	0.8	1.3	1.0
CHINCHILLA K108R					
0.125 kHz	0.0	0.0	1.6	10.9	4.2
0.25 kHz	0.0	0.0	0.3	2.9	1.0
0.5 kHz	1.1	1.2	1.8	2.2	1.7
1 kHz	1.7	87.7	88.1	78.8	84.9
2 kHz	1.3	44.9	44.9	31.8	40.5
4 kHz	0.0	0.6	0.4	0.3	0.4
8 kHz	0.4	0.0	0.8	0.3	0.4
16 kHz	0.0	1.4	0.0	0.0	0.4

GROUP 5: 135 dB - High Peak Impulse - Individual Animal Data (CONTINUED)

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K103R					
0.125 kHz	0.6	3.6	16.4	31.1	17.0
0.25 kHz	0.3	4.4	3.9	13.2	7.1
0.5 kHz	0.3	8.3	6.4	4.4	6.4
1 kHz	71.8	95.2	95.8	78.7	89.9
2 kHz	0.0	42.8	57.0	7.2	35.7
4 kHz	0.7	0.6	3.1	1.1	1.6
8 kHz	0.0	1.2	3.7	1.2	2.0
16 kHz	0.6	2.9	5.0	3.7	3.8
CHINCHILLA K68R					
0.125 kHz	0.0	43.1	38.4	24.4	35.3
0.25 kHz	0.0	0.3	15.1	34.8	16.7
0.5 kHz	0.7	1.7	1.1	6.4	3.1
1 kHz	30.7	35.1	35.0	35.3	35.1
2 kHz	0.0	1.5	0.1	1.3	1.0
4 kHz	0.4	0.6	1.1	1.4	1.0
8 kHz	0.0	0.3	0.9	1.5	0.9
16 kHz	0.0	0.3	0.0	0.6	0.3
CHINCHILLA K116R					
0.125 kHz	2.0	2.6	5.1	11.3	6.3
0.25 kHz	0.0	0.8	0.3	9.1	3.4
0.5 kHz	1.2	0.9	1.5	2.8	1.7
1 kHz	0.0	0.7	0.4	1.4	0.9
2 kHz	0.0	0.7	0.4	0.3	0.5
4 kHz	0.8	0.9	0.3	0.9	0.7
8 kHz	0.0	0.9	0.6	0.0	0.5
16 Khz	0.4	1.7	0.6	2.4	1.6

GROUP 6: 127 dB - Low Peak Impulse

TOTAL NUMBER OF SENSORY CELLS MISSING IN THE ENTIRE COCHLEA

ANIMAL NUMBER	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
K62R	11	119	178	166	463
K115R	7	29	49	72	150
K69R	104	498	479	329	1306
K114R	13	44	84	100	228
K102R	8	27	79	156	262
K93R	10	21	32	45	98
GROUP MEAN	26				418
SD	39				453

GROUP 6: 127 dB - Low Peak Impulse

GROUP MEANS

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND
LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	10 log $\frac{IHC}{1}$	OUTER HAIR CELLS	10 log $\frac{OHC}{10}$
0.125 kHz	2.8	4.5	89.7	9.5
0.25 kHz	1.0	0	44.2	6.5
0.5 kHz	0.8	-1.0	31.0	4.9
1 kHz	11.5	10.6	111.2	10.5
2 kHz	5.8	7.6	112.7	10.5
4 kHz	1.5	1.8	7.8	-1.1
8 kHz	1.5	1.8	9.8	-0.1
16 kHz	1.0	0	11.0	0.4

STANDARD DEVIATIONS

	TOTAL INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
0.125 kHz	3.0	46.0
0.25 kHz	1.3	34.6
0.5 kHz	1.6	21.3
1 kHz	26.2	179.2
2 kHz	12.4	232.4
4 kHz	1.4	3.2
8 kHz	1.0	5.9
16 kHz	0.8	4.9

INDIVIDUAL ANIMAL DATA

GROUP 6: 127 dB - Low Peak Impulse

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K62R					
0.125 kHz	7	34	64	69	167
0.25 kHz	0	11	11	50	72
0.5 kHz	0	18	13	21	52
1 kHz	1	45	28	5	78
2 kHz	2	6	54	1	61
4 kHz	0	1	1	5	7
8 kHz	1	0	3	7	10
16 kHz	0	4	4	8	16
TOTALS	11	119	178	166	463
CHINCHILLA K115R					
0.125 kHz	0	17	32	26	75
0.25 kHz	0	1	4	20	25
0.5 kHz	4	1	1	1	3
1 kHz	0	4	10	21	35
2 kHz	0	2	1	1	4
4 kHz	1	2	1	1	4
8 kHz	2	1	0	1	2
16 kHz	0	1	0	1	2
TOTALS	7	29	49	72	150
CHINCHILLA K69R					
0.125 kHz	0	20	33	27	80
0.25 kHz	3	8	16	76	100
0.5 kHz	0	8	3	12	23
1 kHz	65	202	182	90	474
2 kHz	31	249	235	101	585
4 kHz	3	2	1	7	10
8 kHz	1	6	5	9	20
16 kHz	1	3	4	7	14
TOTALS	104	498	479	329	1306

GROUP 6: 127 dB - Low Peak Impulse - Individual Animal Data (CONTINUED)

TOTAL SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K114R					
0.125 kHz	2	6	32	62	100
0.25 kHz	2	6	3	13	22
0.5 kHz	1	11	21	11	43
1 kHz	2	4	15	3	22
2 kHz	0	7	1	0	8
4 kHz	3	1	4	1	6
8 kHz	3	3	2	6	11
16 kHz	0	4	5	4	13
TOTALS	13	44	84	100	228
CHINCHILLA K102R					
0.125 kHz	2	10	42	39	91
0.25 kHz	1	4	14	18	36
0.5 kHz	0	3	13	37	53
1 kHz	1	2	2	42	46
2 kHz	2	2	1	9	12
4 kHz	0	4	2	1	7
8 kHz	2	2	2	3	7
16 kHz	0	0	3	7	10
TOTALS	8	27	79	156	262
CHINCHILLA K93R					
0.125 kHz	6	2	5	18	25
0.25 kHz	0	5	3	2	10
0.5 kHz	0	1	9	2	12
1 kHz	0	2	4	6	12
2 kHz	0	2	1	3	6
4 kHz	2	2	4	7	13
8 kHz	0	4	2	3	9
16 kHz	2	3	4	4	11
TOTALS	10	21	32	45	98

GROUP 6: 127 dB - Low Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	TOTAL OUTER HAIR CELLS
GROUP MEANS		
0.125 kHz	2.0	15.7
0.25 kHz	0.4	4.1
0.5 kHz	0.4	3.1
1 kHz	6.0	12.6
2 kHz	0.9	9.8
4 kHz	0.5	0.8
8 kHz	0.6	1.0
16 kHz	0.2	1.3
STANDARD DEVIATIONS		
0.125 kHz	2.0	7.5
0.25 kHz	0.5	3.1
0.5 kHz	0.7	2.1
1 kHz	13.9	21.6
2 kHz	1.3	19.7
4 kHz	0.5	0.3
8 kHz	0.4	0.5
16 kHz	0.4	0.6

INDIVIDUAL ANIMAL DATA

GROUP 6: 127 dB - Low Peak Impulse

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K114R					
0.125 kHz	1.5	3.0	15.9	31.0	16.6
0.25 kHz	0.7	1.7	0.9	3.5	2.0
0.5 kHz	0.4	3.1	6.2	3.1	4.1
1 kHz	0.8	1.4	4.2	0.9	2.2
2 kHz	0.4	1.8	0.6	0.0	0.8
4 kHz	0.8	0.3	0.9	0.6	0.6
8 kHz	1.1	0.9	0.6	1.5	1.0
16 kHz	0.0	1.9	1.9	1.3	1.7
CHINCHILLA K102R					
0.125 kHz	1.3	5.0	20.9	19.6	15.2
0.25 kHz	0.4	1.1	4.4	5.2	3.6
0.5 kHz	0.0	0.8	3.1	11.4	5.1
1 kHz	0.7	0.6	0.6	11.8	4.3
2 kHz	0.4	0.6	0.3	2.1	1.0
4 kHz	0.0	1.2	0.6	0.3	0.7
8 kHz	0.7	0.6	0.6	0.9	0.7
16 kHz	0.0	0.0	1.0	2.3	1.1
CHINCHILLA K93R					
0.125 kHz	4.3	1.4	2.7	9.8	4.6
0.25 kHz	0.0	1.4	1.1	0.6	1.0
0.5 kHz	0.0	0.3	2.6	1.0	1.3
1 kHz	0.0	0.7	1.3	1.9	1.3
2 kHz	0.0	0.6	0.3	1.0	0.7
4 kHz	0.8	0.6	1.3	1.8	1.2
8 kHz	0.0	1.3	0.6	1.3	1.1
16 kHz	0.9	1.1	1.4	1.1	1.2

GROUP 6: 127 dB - Low Peak Impulse - Individual Animal Data (CONTINUED)

% SENSORY CELL LOSSES OVER OCTAVE BAND LENGTHS OF THE COCHLEA CENTERED AT THE FREQUENCIES INDICATED

OCTAVE BAND CENTER FREQUENCY	INNER HAIR CELLS	1ST ROW OUTER HAIR CELLS	2ND ROW OUTER HAIR CELLS	3RD ROW OUTER HAIR CELLS	TOTAL OUTER HAIR CELLS
CHINCHILLA K62R					
0.125 kHz	4.6	17.1	32.2	34.8	28.0
0.25 kHz	0.0	3.1	3.1	14.3	6.9
0.5 kHz	0.3	6.6	3.9	6.0	5.5
1 kHz	0.1	12.3	8.6	1.3	7.4
2 kHz	0.8	1.5	15.6	0.6	5.9
4 kHz	0.0	0.3	0.3	1.2	0.6
8 kHz	0.4	0.0	0.9	2.1	1.0
16 kHz	0.0	1.3	1.2	2.6	1.7
CHINCHILLA K115R					
0.125 kHz	0.0	9.5	18.3	15.0	14.3
0.25 kHz	0.0	0.3	1.0	6.0	2.4
0.5 kHz	1.7	0.3	0.3	0.6	0.4
1 kHz	0.0	1.3	3.3	6.7	3.8
2 kHz	0.0	0.7	0.3	0.3	0.4
4 kHz	0.4	0.7	0.3	0.4	0.5
8 kHz	0.8	0.3	0.0	0.2	0.2
16 kHz	0.0	0.4	0.0	0.4	0.2
CHINCHILLA K69R					
0.125 kHz	0.0	12.1	17.3	16.7	15.3
0.25 kHz	1.2	1.2	4.3	20.8	8.8
0.5 kHz	0.0	3.1	0.9	3.2	2.4
1 kHz	34.3	69.6	64.2	35.7	56.5
2 kHz	3.5	65.8	61.6	21.9	49.8
4 kHz	1.1	0.9	0.5	2.2	1.2
8 kHz	0.4	1.5	1.3	2.5	1.8
16 kHz	0.4	1.0	1.3	2.3	1.6

APPENDIX E

BACKGROUND FOR THE COMPUTATION OF EXPOSURE ENERGY LEVELS*

The following equation was used to calculate the energy transported with an impulse per unit of area.

$$W = \frac{1}{\rho c} \int_{-\infty}^{\infty} p^2(t)\, dt \qquad (1)$$

The following definitions apply:

W is energy per unit area transported in the specified direction (joules/M^2).

P(t) is the instantaneous pressure as a function of time (Pa).

ρc is the specific acoustic impedance taken as 410 rayls (N.Sec/M^3) for air.

This equation is subject to the assumption that the impulse measured in the far field is a plane wave. It should be noted that the pressure measurements were made without the animal in position, but at the point in space approximating the entrance to the animal's ear canal during the exposures. Equation (1) then was approximated by digital integration of a time series representing P(t) for a single impulse. This value then was converted to a level by

$$L\varepsilon = 10 \log W/Wo \qquad (2)$$

where Wo was taken to be 1 joule/M^2. The exposure energy (EE) level for each experimental condition then was calculated by

$$EE = L\varepsilon + 10 \log N \qquad (3)$$

where N is the number of impulses in the exposure.

* Young, R. W., 1970. On the energy transported with a sound pulse. The Journal of the Acoustical Society of America. 47:441-442.

APPENDIX F

LIST OF MANUFACTURERS

Altec Lansing Corporation
1515 S. Manchester Avenue
Anaheim, CA 92803

Bruel and Kjaer Instruments, Incorporated
9047-A Gaither Road
Gaithersburg, MD 20760

John Fluke Manufacturing Company, Incorporated
P. O. Box 43210
Mountlake Terrace, WA 98043

Industrial Acoustics Corporation
380 Southern Boulevard
Bronx, NY 10454

Nagra Magnetic Recorders, Incorporated
19 West 44th Street, Room 715
New York, NY 10036

Rockland Systems Corporation
230 West Nyack Road
West Nyack, NY 10994

Carl Zeiss, Incorporated
444 5th Avenue
New York, NY 10018

INITIAL DISTRIBUTION

Commander
US Army Natick Research and
Development Center
ATTN: Documents Librarian
Natick, MA 01760

Commander
US Army Research Institute of
Environmental Medicine
Natick, MA 01760

Naval Submarine Medical Research
Laboratory
Medical Library, Naval Sub Base
Box 900
Groton, CT 05340

US Army Avionics Research and
Development Activity
ATTN: SAVAA-P-TP
Fort Monmouth, NJ 07703-5401

Commander/Director
US Army Combat Surveillance and
Target Acquisition Laboratory
ATTN: DELCS-D
Fort Monmouth, NJ 07703-5304

US Army Research and Development
Support Activity
Fort Monmouth, NJ 07703

Commander
10th Medical Laboratory
ATTN: Audiologist
APO New York 09180

Chief, Benet Weapons Laboratory
LCWSL, USA ARRADCOM
ATTN: DRDAR-LCB-TL
Watervliet Arsenal, NY 12189

Commander
Naval Air Development Center
Biophysics Lab (ATTN: G. Kydd)
Code 60B1
Warminster, PA 18974

Commander
Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

Naval Air Development Center
Technical Information Division
Technical Support Detachment
Warminster, PA 18974

Commander
Naval Air Development Center
ATTN: Code 6021 (Mr. Brindle)
Warminster, PA 18974

Dr. E. Hendler
Human Factors Applications, Inc.
295 West Street Road
Warminster, PA 18974

Commanding Officer
Naval Medical Research and
Development Command
National Naval Medical Center
Bethesda, MD 20014

Under Secretary of Defense for
Research and Engineering
ATTN: Military Assistant for
Medical and Life Sciences
Washington, DC 20301

Director
Army Audiology and Speech Center
Walter Reed Army Medical Center
Washington, DC 20307-5001

COL Franklin H. Top, Jr., MD
Walter Reed Army Institute
of Research
Washington, DC 20307-5100

Commander
US Army Institute of Dental Research
Walter Reed Army Medical Center
Washington, DC 20307-5300

HQ DA (DASG-PSP-O)
Washington, DC 20310

Naval Air Systems Command
Technical Library Air 950D
Rm 278, Jefferson Plaza II
Department of the Navy
Washington, DC 20361

Naval Research Laboratory Library
Code 1433
Washington, DC 20375

Naval Research Laboratory Library
Shock & Vibration Information Center
Code 5804
Washington, DC 20375

Harry Diamond Laboratories
ATTN: Tech Information Branch
2800 Powder Mill Road
Adelphi, MD 20783-1197

Director
US Army Human Engineering Laboratory
ATTN: Technical Library
Aberdeen Proving Ground, MD
21005-5001

US Army Materiel Systems
Analysis Agency
ATTN: Reports Processing
Aberdeen Proving Ground, MD
21005-5017

Commander
US Army Test & Evaluation Command
ATTN: AMSTE-AD-H
Aberdeen Proving Ground, MD
21005-5055

US Army Ordnance Center
& School Library
Bldg 3071
Aberdeen Proving Ground, MD
21005-5201

Director
US Army Ballistic Research Laboratory
ATTN: DRXBR-OD-ST Tech Reports
Aberdeen Proving Ground, MD
21005-5066

US Army Environmental Hygiene
Agency Library
Bldg E2100
Aberdeen Proving Ground, MD 21010

Commander
US Army Medical Research Institute
of Chemical Defense
ATTN: SGRD-UV-AO
Aberdeen Proving Ground, MD
21010-5425

Technical Library
Chemical Research & Development Center
Aberdeen Proving Ground, MD
21010-5423

Commander
US Army Medical Research
& Development Command
ATTN: SGRD-RMS (Mrs. Madigan)
Fort Detrick, Frederick, MD
21701-5012

Commander
US Army Medical Research Institute
of Infectious Diseases
Fort Detrick, Frederick, MD 21701

Commander
US Army Medical Bioengineering
Research & Development Laboratory
ATTN: SGRD-UBZ-I
Fort Detrick, Frederick, MD 21701

Dr. R. Newburgh
Director, Biological Sciences Division
Office of Naval Research
600 North Quincy Street
Arlington, VA 22217

Defense Technical Information Center
Cameron Station
Alexandria, VA 22314

Commander
US Army Materiel Command
ATTN: AMCDE-S (CPT Broadwater)
5001 Eisenhower Avenue
Alexandria, VA 22333

US Army Foreign Science and
Technology Center
ATTN: MTZ
220 7th Street, NE
Charlottesville, VA 22901-5396

Commandant
US Army Aviation Logistics School
ATTN: ATSQ-TDN
Fort Eustis, VA 23604

Director, Applied Technology Lab
USARTL-AVSCOM
ATTN: Library, Bldg 401
Fort Eustis, VA 23604

US Army Training and
Doctrine Command
ATTN: ATCD-ZX
Fort Monroe, VA 23651

US Army Training and
Doctrine Command
ATTN: Surgeon
Fort Monroe, VA 23651-5000

Structures Laboratory Library
USARTL-AVSCOM
NASA Langley Research Center
Mail Stop 266
Hampton, VA 23665

Aviation Medicine Clinic
TMC #22, SAAF
Fort Bragg, BC 28305

Naval Aerospace Medical
Institute Library
Bldg 1953, Code 102
Pensacola, FL 32508

US Air Force Armament Development
and Test Center
Eglin Air Force Base, FL 32542

Command Surgeon
US Central Command
MacDill AFB, FL 33608

US Army Missile Command
Redstone Scientific Information Center
ATTN: Documents Section
Redstone Arsenal, AL 35898-5241

Air University Library
(AUL/LSE)
Maxwell AFB, AL 36112

Commander
US Army Aeromedical Center
Fort Rucker, AL 36362

Commander
US Army Aviation Center & Fort Rucker
ATTN: ATZQ-CDR
Fort Rucker, AL 36362

Directorate of Combat Developments
Bldg 507
Fort Rucker, AL 36362

Directorate of Training Development
Bldg 502
Fort Rucker, AL 36362

Chief
Army Research Institute Field Unit
Fort Rucker, AL 36362

Chief
Human Engineering Labs Field Unit
Fort Rucker, AL 36362

Commander
US Army Safety Center
Fort Rucker, AL 36362

Commander
US Army Aviation Center & Fort Rucker
ATTN: ATZQ-T-ATL
Fort Rucker, AL 36362

US Army Aircraft Development
Test Activity
ATTN: STEBG-MP-QA
Cairns AAF, Ft Rucker, AL 36362

President
US Army Aviation Board
Cairns AAF, Ft Rucker, AL 36362

US Army Research & Technology
Laboratories (AVSCOM)
Propulsion Laboratory MS 302-2
NASA Lewis Research Center
Cleveland, OH 44135

AFAMRL/HEX
Wright-Patterson AFB, OH 45433

US Air Force Institute of Technology
(AFIT/LDEE)
Bldg 640, Area B
Wright-Patterson AFB, OH 45433

University of Michigan
NASA Center of Excellence
in Man-Systems Research
ATTN: R.G. Snyder, Director
Ann Arbor, MI 48109

Henry L. Taylor
Director, Institute of Aviation
Univ of Illinois - Willard Airport
Savoy, IL 61874

John A. Dellinger, MS, ATP
Univ of Illinois - Willard Airport
Savoy, IL 61874

Commander
US Army Aviation Systems Command
ATTN: DRSAV-WS
4300 Goodfellow Blvd
St Louis, MO 63120-1798

Project Officer
Aviation Life Support Equipment
ATTN: AMCPO-ALSE
4300 Goodfellow Blvd
St Louis, MO 63120-1798

Commander
US Army Aviation Systems Command
ATTN: SGRD-UAX-AL (MAJ Lacy)
Bldg 105, 4300 Goodfellow Blvd
St Louis, MO 63120

Commander
US Army Aviation Systems Command
ATTN: DRSAV-ED
4300 Goodfellow Blvd
St Louis, MO 63120

US Army Aviation Systems Command
Library & Info Center Branch
ATTN: DRSAV-DIL
4300 Goodfellow Blvd
St Louis, MO 63120

Commanding Officer
Naval Biodynamics Laboratory
P.O. Box 24907
New Orleans, LA 70189

Federal Aviation Administration
Civil Aeromedical Institute
CAMI Library AAC 64D1
P.O. Box 25082
Oklahoma City, OK 73125

US Army Field Artillery School
ATTN: Library
Snow Hall, Room 14
Fort Sill, OK 73503

Commander
US Army Academy of Health Sciences
ATTN: Library
Fort Sam Houston, TX 78234

Commander
US Army Health Services Command
ATTN: HSOP-SO
Fort Sam Houston, TX 78234-6000

Commander
US Army Institute of Surgical Research
ATTN: SGRD-USM (Jan Duke)
Fort Sam Houston, TX 78234-6200

Director of Professional Services
AFMSC/GSP
Brooks Air Force Base, TX 78235

US Air Force School
of Aerospace Medicine
Strughold Aeromedical Library
Documents Section, USAFSAM/TSK-4
Brooks Air Force Base, TX 78235

US Army Dugway Proving Ground
Technical Library
Bldg 5330
Dugway, UT 84022

Dr. Diane Damos
Department of Human Factors
ISSM, USC
Los Angeles, CA 90089-0021

US Army Yuma Proving Ground
Technical Library
Yuma, AZ 85364

US Army White Sands Missile Range
Technical Library Division
White Sands Missile Range, NM 88002

US Air Force Flight Test Center
Technical Library, Stop 238
Edwards Air Force Base, CA 93523

US Army Aviation Engineering
Flight Activity
ATTN: SAVTE-M (Tech Lib) Stop 217
Edwards AFB, CA 93523-5000

Commander
Code 3431
Naval Weapons Center
China Lake, CA 93555

US Army Combat Developments
Experimental Center
Technical Information Center
Bldg 2925
Fort Ord, CA 93941-5000

Aeromechanics Laboratory
US Army Research
& Technical Laboratories
Ames Research Center, M/S 215-1
Moffett Field, CA 94035

Commander
Letterman Army Institute of Research
ATTN: Medical Research Library
Presidio of San Francisco, CA 94129

Sixth US Army
ATTN: SMA
Presidio of San Francisco, CA 94129

Director
Naval Biosciences Laboratory
Naval Supply Center, Bldg 844
Oakland, CA 94625

Col G. Stebbing
USDAO-AMLO, US Embassy
Box 36
FPO New York 09510

Staff Officer, Aerospace Medicine
RAF Staff, British Embassy
3100 Massachusetts Avenue, NW
Washington, DC 20008

Canadian Society of Aviation Medicine
c/o Academy of Medicine, Toronto
ATTN: Ms. Carmen King
288 Bloor Street West
Toronto, Ontario M55 1V8

Canadian Airline Pilot's Association
MAJ J. Soutendam (Retired)
1300 Steeles Avenue East
Brampton, Ontario, L6T 1A2

Canadian Forces Medical Liaison Officer
Canadian Defence Liaison Staff
2450 Massachusetts Avenue, NW
Washington, DC 20008

Commanding Officer
404 Squadron CFB Greenwood
Greenwood, Nova Scotia BOP 1NO

Officer Commanding
School of Operational
& Aerospace Medicine
DCIEM, P.O. Box 2000
1133 Sheppard Avenue West
Downsview, Ontario M3M 3B9

National Defence Headquarters
101 Colonel By Drive
ATTN: DPM
Ottowa, Ontario K1A OK2

Commanding Officer
Headquarters, RAAF Base
POINT COOK VIC 3029
Australia

Canadian Army Liaison Office
Bldg 602
Fort Rucker, AL 36362

Netherlands Army Liaison Office
Bldg 602
Fort Rucker, AL 36362

German Army Liaison Office
Bldg 602
Fort Rucker, AL 36362

British Army Liaison Office
Bldg 602
Fort Rucker, AL 36362

French Army Liaison Office
Bldg 602
Fort Rucker, AL 36362

ABSTRACT:

Most current Damage Risk Criteria (DRC) for human exposure to impulse noise are written in terms of peak pressure as the primary index of the traumatic potential or hazard associated with exposure to an impulse noise. Since the peak pressure is only one of many parameters of an impulse, there is a question whether or not a DRC based on peak pressure can reflect accurately the hazard to hearing posed by impulse noise. The experiments described in this report were designed to determine whether peak pressure is an adequate quantifier for an impulse noise DRC. The general approach was to construct two types of impulse noise with the same Fourier pressure spectrum, but with different peak pressures. This makes it possible to compare the hearing loss and injury resulting from impulses which have the same total energy distributed the same way across frequency, but with different peak pressures. We also can compare injury from different levels. A total of 36 animals were divided into six groups (six animals/group). Groups 1 and 2 were exposed to impulses having approximately equal energy, but with peak pressures that differed by 8 dB. Similarly, groups 3 and 4 and groups 5 and 6 formed pairs of exposure groups where the energy was equivalent, but the peak pressure differed by 8 dB. Threshold shift was measured for 30 days postexposure and injury to the cochlea was determined by examination of surface preparations of the basilar membrane. The threshold shift measured during the first few hours after exposure showed systematic variation with both peak pressure and energy level. The permanent threshold shift (20 to 30 days postexposure) and the loss of sensory cells showed strong dependence on energy level, with a less pronounced dependence on peak pressure. These results indicate that peak pressure is not a sufficient indicator of auditory hazard; however, energy alone is not a sufficient indicator either.